Dimensions of Proximity and Localisation of Knowledge-Intensive Producer Services: the Case of Software Services for Automotive Industry in Stuttgart Region

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Stuttgart, den 8. Oktober 2008

"…the most important things in life are non-communicable, not compressible into words, even though the people who believe they have discovered them always try to communicate them…"

Ivan Klima, in 'Love and garbage'

"Progress lives from the exchange of knowledge."

Albert Einstein

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List of abbreviations

ACEA	European Automobile Manufacturers Association (in French: Association des Constructeurs Européens d'Automobiles)
ASEAN	Association of Southeast Asian Nations
AUTOSAR	AUTomotive Open System Architecture
BRIC	Brazil, Russia, India and China
BW	Baden-Württemberg
CAD	computer-aided design
CAE	computer-aided engineering
CAM	computer-aided manufacturing
CAN	controller-area network
DG	Directorate-General
eBusiness	Electronic Business
EE	electrics and electronics
ERP	enterprise resource planning
et al.	and others (in Latin: et alii)
EU	European Union
Euro NCAP	European New Car Assessment Program
F2F	face-to-face
Fig.	figure
FKFS	Research Institute of Automotive Engineering and Vehicle Engines (in German: Forschungsinstitut für Kraftfahrwesen und Fahrzeugmotoren Stuttgart)
GPT	general purpose technology
GVA	gross value-added
HIS	‘Car Manufacturers’ Software Initiative’ (in German: Hersteller Initiative Software)
ibid.	in the same book, chapter, page, etc. (in Latin: ibidem)

ICT	information and communication technology
IHK	Chamber of Industry and Commerce (in German: Industrie- und Handelskammer)
IPC	International Patent Classification
IT	information technology
IVK	Institute of Combustion Engines and Automotive Engineering (in German: Institut für Verbrennungsmotoren und Kraftfahrwesen)
JIS	just-in-sequence
JIT	just-in-time
KIBS	knowledge-intensive business services
KIPS	knowledge-intensive producer services
M&A	mergers and acquisitions
MFG-BW	in German: Medien- und Filmgesellschaft Baden-Württemberg
MMI	man-machine interface
MOST	media oriented system transport
NACE	statistical classification of economic activities in the European Community (in French: Nomenclature statistique des activités économiques dans la Communauté européenne)
NAFTA	North American Free Trade Agreement
No.	number of
NUTS	Nomenclature of Territorial Units for Statistics (in French: nomenclature d'unités territoriales statistiques)
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
OICA	International Organization of Motor Vehicle Manufacturers (in French: Organisation Internationale des Constructeurs d'Automobiles)
p.	page
PLM	product lifecycle management

pp.	pages
R&D	research and development
SCM	supply-chain management
SME	small and medium sized enterprise
VDA	Association of German Automobile Manufacturers (in German: Verband der Automobilindustrie)
VDC	Virtual Dimension Centre
viz.	that is to say (in Latin: videlicet)
VRS	Verband Region Stuttgart
WRS	Stuttgart Region Economic Development Cooperation (in German: Wirtschaftsförderung Region Stuttgart)
ZW	branches of trade (in German: Wirtschaftszweige)

Preface

The preparation of this thesis has been a challenging and rewarding experience that has enabled me to combine my personal and research interest in communication, business and economic geography topics, as well as in automotive and software sectors. I am indebted to my advisor Prof. Dr. Gaebe, who has been of great help with his advice and his assistance to establish my course of research. I shall also thank Prof. Dr. Hahn for our discussions and for accepting the role of the second thesis advisor at such short notice.

For the last three years, I was in the fortunate position to experience the practical side of regional economics at the Stuttgart Region Economic Development Cooperation. I am thankful to my colleagues for their support and their inputs. I shall also extend my sincere thanks the numerous experts who have shared their knowledge and experience with great generosity. Without their inputs this study would not have been possible.

I am grateful for the cooperation and support of my colleagues at the Institute for Geography of University of Stuttgart: Ingrid Eibner, Iris Gebauer, Gerhard Halder, Ralf Binder and Björn Sautter. Their tips, advice and feed-back on everything from methodology to economic geography in general have made my adaptation much easier as a late-comer to this field. I shall also express my special gratitude for Simone Plahuta for her unremitting support and encouragement.

I shall thank Anja for her loving patience and support through the long last part of this study and a big “thank you” goes to Lou as well for the telephone calls and the singing. Without their presence it could have been much harder to take this to the end. Finally, I would like to dedicate this work to my late parents Fatma and Necati Tözün.

Stuttgart, October 2008 Reha Tözün

Abstract (English)

This thesis primarily examines the spatiality of knowledge-intensive producer services within the framework of knowledge tacitness and aspatial proximities notions. Additionally, based on an example of a West-European location, it links aspatial proximities and regional structural change discourses and explores the significance of lead firms for regional agglomerations.

Globalization operates on the significantly lowered trade barriers and mobility of goods, persons and information. In such an environment, knowledge-production and innovation are critical elements of industrial competitiveness, especially for developed countries in Western Europe. As it has been suggested since late 1980’s, innovation has a strong interactive component and the knowledge-creation processes tend to localize geographically. However, such processes are do function over geographical distance as well; therefore one needs to consider the non-geographical influences to understand the dynamics involved. The aspatial proximities, which are categorized by Boschma along cognitive, social, organisational and institutional dimensions, provide an intriguing framework to handle the issues regarding the spatiality of knowledge-producing relations between economic actors.

Despite the awareness regarding the role of interaction, theories on regional agglomeration phenomenon tend to be more attentive to the supply-side matters. However, the impulses and incentives from demand side do co-define the direction and extent of knowledge production efforts. With the important roles it assigns to local demand and customers, Porter’s industrial clusters concept offers a theoretical background for the research interests of this study.

Beside aspatial proximities and industrial clusters, this thesis draws on learning regions, long-waves of technological change and regional structural change literatures for its framework of analysis. For the empirical investigation software services for automotive industry in the Stuttgart region were selected. In-depth interviews with regional experts were adopted for the purposes of data collection.

The knowledge-intensive producer services relations fundamentally depend on application- and customer-specific knowledge, which is often change-prone and not market-traded. The study revealed that the well-maintained aspatial proximities allow service providers to have sustained access to such knowledge. It was also found that the creation and maintenance of aspatial proximities is related to the availability of spatial proximity between actors and groups. As such, geographical space has a subtle and indirect effect on knowledge production in that it influences cognitive, social and organisational space through which knowledge is

generated and shared. The management of aspatial proximities is also a crucial factor for the path-dependant agglomeration of services activities around existing production locations.

The study also found out that the coordination challenges induced by the cognitive dynamics of knowledge-production processes strongly affect the spatial proximity requirements of interactive relations. Cognitive dynamics is defined by the tacitness of knowledge content and the processes characteristics. While tacitness creates the need for face-to-face exchanges, time constraints and interfaces between knowledge-production processes compel actors to have more frequent meetings. Under conditions where highly tacit knowledge content has to be co-produced and shared in short time intervals across numerous processes run by different teams, groups of actors are compelled to engage in more frequent face-to-face interaction in order to avoid knowledge mismatches and miscomprehension. As such, the serviceability of such relations decreases with distance and increasing geographical space between partners escalates transaction costs, which in return impels parties to locate near each other. However, the codifiability of knowledge content and the manageability of processes change these dynamics and spatial proximity becomes a choice rather than a requirement.

Provided that their operations contain active technology-oriented and knowledge-production functions, lead firms can act as the nodes of regional knowledge-production networks in clusters. The evidence collected for this study suggests that besides acting as demanding local customers à la Porter, they actively co-develop innovations and enrich knowledge capital of a cluster.

Abstract (German)

Das Kernthema dieser Arbeit ist die Bedeutung räumlicher und nicht-räumlicher Nähe für wissensintensive und produktionsnahe Dienstleistungen. Den theoretischen Forschungsrahmen bilden Untersuchungen zu impliziten Wissen und Nähe. Darüber hinaus verbindet sie Diskurse über nicht-räumlicher Nähe und regionalen Strukturwandel und versucht die Arbeit die Bedeutung von Leitunternehmen für regionale Branchenkonzentrationen zu bestimmen.

Globalisierung umfasst erheblich geringere Handelsbarrieren, Mobilität von Gütern, Personen und Informationen. In einem solchen Umfeld sind Wissensproduktion und Innovation die Kernelemente der industriellen Wettbewerbsfähigkeit. Dies gilt besonders für die entwickelten Länder Westeuropas. Wie es bereits in den späten 80er Jahren angenommen wurde, hat Innovation einen stark interaktiven Aspekt und Wissensproduktion neigt sich zur Lokalisation. Diese Prozesse beschränken sich jedoch nicht auf die regionale Ebene. Folglich muss man ebenso die nicht-räumlichen Einflüsse berücksichtigen. Das Konzept nicht-räumlicher Nähe stellt einen Handlungsrahmen für die Untersuchung von wissensproduzierenden Beziehungen zwischen Wirtschaftsakteuren. Boschma unterteilt diese in kognitive, soziale, organisatorische und industrielle Dimensionen.

Obwohl die Bedeutung der Interaktion in der geographischen Literatur betont wurde, befassten sich die Theorien über regionale Agglomerationen vorwiegend mit der Anbieterseite. Indes bestimmen die Impulse und Anreize der Nachfrageseite die Richtung und den Umfang von Bestrebungen zur Wissensproduktion. Das Clusterkonzept von Porter legt unter anderem einen Schwerpunkt auf regionale Nachfrage und Kunden. Aus diesem Grund bildet dieses Konzept einen wichtigen theoretischen Hintergrund der vorliegenden empirischen Arbeit.

Neben dem Konzept der nicht-räumlichen Nähe und der Clustertheorie, stützt sich diese Studie auf Literatur über lernende Regionen, die langen Wellen und den regionalen Strukturwandel. Den empirischen Mittelpunkt dieser Arbeit bilden Softwaredienstleistungen für die Automobilindustrie in der Region Stuttgart. Zur Datenerfassung wurden Leitfadeninterviews mit regionalen Experten durchgeführt.

Die wissensintensiven Dienstleistungen für das produzierende Gewerbe sind von kunden- und anwendungsspezifischem Wissen abhängig, das einem schnellen Wandel unterliegt und nicht käuflich zu erwerben ist. Im Rahmen der Studie wurde festgestellt, dass die nicht-räumlichen

Arten von Nähe den Softwaredienstleistern einen dauerhaften Zugang zu diesem Wissen ermöglichen.

Die vorliegende Studie konnte feststellen, dass in interaktiven Beziehungen die kognitive Dynamik der Wissensproduktionsprozesse das Bedürfnis nach räumlicher Nähe sehr stark beeinflusst. Diese kognitive Dynamik an sich wird durch implizite Wissens- und Prozesscharakteristiken bestimmt. Das implizite Wissen schafft den Bedarf für persönliche Interaktionen. Gleichzeitig verstärken der knappe zeitliche Rahmen und die inhaltlichen Überschneidungen zwischen unterschiedlichen Wissensproduktionsprozessen den Bedarf der Beteiligten, sich häufiger zu treffen. Wenn hoch impliziter Wissensinhalt in kurzen Zeiträumen durch verschiedene Prozesse und Teams entwickelt und verteilt werden muss, sind die Beteiligten dazu aufgefordert, häufigere Interaktionen zu unternehmen, um Nichtübereinstimmungen und Missverständnisse zu vermeiden. Die Zweckdienlichkeit solcher Beziehungen sinkt mit der Distanz und geographischer Raum erhöht die Transaktionskosten. Demzufolge liegt es im Interesse der Beteiligten geographisch nah zu arbeiten. Die Kodifizierbarkeit des Wissens und die Handlichkeit der Prozesse ändern jedoch diese Dynamiken und geographische Nähe wird somit eher eine Option als Pflicht erscheinen.

Leitfirmen können die Rolle von Netzwerkknoten in den Clustern übernehmen, vorausgesetzt ihre örtlichen Aktivitäten beinhalten aktive technologieorientierte Wissensproduktion. Das Ergebnis dieser Studie weist darauf hin, dass die Leitfirmen die Rolle von anspruchvollen Kunden übernehmen und darüber hinaus das Wissenskapital der Cluster bereichern können.

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1. Introduction

1.1. Definition of research problem

Globalization operates on lowered trade barriers and mobility of goods, persons and information. While the enterprises enjoy the variety of locational options available to them, traditional Western European industrial regions find themselves under an elevated risk of structural change. In such an environment, preventing destructive structural change appears to lie in a location's ability to maintain a high-level of knowledge-production capacity and to stimulate innovation-inducing relations. As well as the policy makers, the academic realm has been giving a lot of attention during the last decades to the sub-national level structures (OECD 1999 and 2001). Different groups of scholars have proposed alternative lines of explanation for the regional agglomeration phenomena by offering different concepts like industrial districts, cluster and learning regions (Brusco 1990, Piore/Sabel 1984, Porter 1998a, Cooke 1998, Asheim 1996 and Malmberg 1997). For a long period Schumpeter influenced the associated discussions around innovation with his arguments relating to the role of innovator and later on to the function of the large enterprises. However, starting with late 1980s, the interactive nature of innovation came under spotlight (Lundvall/Johnson 1994, Dosi 1988) and building on these accounts numerous economic geographers took it on themselves to investigate the spatiality of interactive innovation. The outcome appeared as innovation systems and learning regions literatures, which placed the localisation of interaction at the centre of their arguments.

For this study, literature on learning regions has been one of the foci of interest and reference. Here, the localized means of knowledge-production are embedded in traded and untraded regional relations as well as in material and immaterial regional structures (Florida 1995, Storper 1997 pp. 107-133, Malmberg/Maskell 2002, 2006). The significance of tacit knowledge is underlined and its resistance to spatial distance is suggested as a driver for the agglomeration of knowledge-intensive activity (Gertler 2003). In a learning region knowledge-production processes function along vertical and horizontal dimensions and localized relations create learning outcomes through partially unintended social exchanges. However, some authors rightly argued that neither vertical, nor horizontal, nor social dimensions of learning are spatially confined at the regional level (Bathelt et al. 2004). Yet even others, namely the Proximity Dynamics Group of France, started to argue for the existence and importance of aspatial proximities between actors and enterprises (Rallet/Torre 1999, Torre/Gilly 2000, Torre/Rallet 2005). Boschma contributed to this discussion by suggesting a multidimensional representation of aspatial proximities, which this study adopted as an analytical tool for analysis (Boschma 2005).

Although not an economic geographer, Porter made a massive impact on the discourse over agglomeration economies with his concept of industrial clusters (Porter 1998a and 2000). Discussions on regional agglomerations tend to deal with supply side issues and in comparison, Porter’s approach assigns demand and local customers important roles, which is a distinguishing character of his concept. As such, his cluster concept has a link to the interactive innovation notion, for which customers are not only stimulants but also co-producers of innovation.

This study also wishes to make the “close and symbiotic” relation between manufacturing and services a point of focus (OECD 2000 p. 9). Therefore, the relations around the knowledge-intensive producer services for the automotive industry will provide a sectoral case of analysis. Automotive industry is a very intriguing sector in itself. It is not only a mature but also a dynamic industry, which combines globalisation and localization in its spatial organisation. Besides, although it is considered by Eurostat to be a medium-high-tech industry, automotive makes use of diverse inputs from high-tech sectors to manufacture technologically sophisticated products (Felix 2006 p. 7). Specialized software services are part of the high-tech knowledge-intensive producer services that provide such inputs and enable process and product innovation in the automotive sector.

The automotive firms investigated in this study operate through global networks of operations and exchange relationships; thereby they have access to locations around the globe. On the other hand, the software firms are technologically capable and well-placed to utilize the IT-tools to provide services globally. Hence both groups have options to engage in business relations over distance. Yet, the software services for automotive industry display a tendency to concentrate around selected locations.

On this briefly summarised background, the research questions for which answers will be sought are as follows:

Research question I

What is the relation between the knowledge content of producer services and their spatial proximity requirements?

Research question II

What is the relation between spatial and aspatial (social, organizational, institutional and cognitive) proximities for knowledge-intensive producer services?

Research question III

What role is played by regional lead firms for knowledge-intensive producer services activity?

Research question IV

What can be inferred from the case of knowledge-intensive producer services for the discourse on regional structural change?

The geographical boundary of the research activity is Stuttgart region in South-West Germany, which comprises the city of Stuttgart and its five neighbouring counties Böblingen, Esslingen, Göppingen, Ludwigsburg and Rems-Murr. Stuttgart region is literally the birthplace of the automobile and has a long tradition of car-making. Today, a high concentration of activity related to the automotive sector, associated academic and research institutions and other relevant actors are located here. Especially the headquarters and R&D centres of two car-makers (Daimler AG and Porsche AG) and several high-level suppliers (Robert Bosch, Mahle, Behr and Mann+Hummel among others) create a rare density of automotive-oriented R&D activity. The software services activity in the region has also been growing over the years and software services aimed at automotive industry can also be identified.

By analysing this case example, the study aims to achieve three objectives: a contribution to the aspatial proximities discourse and the concept suggested by Boschma, an analysis of the regional role played by lead enterprises in terms of knowledge-intensive activities and observations on regional structural change process within the context of knowledge-intensive producer services.

1.2. Outline of this document

This study consists of five sections as depicted in Fig. 1. The structure of the study stems from the research questions stated in the first section. The second section describes the theoretical background of the study with an analysis of theme-relevant literature. Here three main thematic strands can be seen. The first is a presentation and discussion of concepts and literature regarding knowledge and proximity and is, as such, a crucial section for the investigation of the research questions on hand. The respective key notions of tacit and codified knowledge are explained and their associations with knowledge-production processes are discussed (Sections 2.1.2 and 2.1.3). Thereafter, the aspatial proximity notion is presented by comparing the contributions of the French Proximity Dynamics Group with Boschma's approach. Here, the reasons for adopting the latter's representation of aspatial proximities are outlined and afterwards complemented by geographical reflections on aspatial proximities (Sections 2.1.3 and 2.1.4).

The second part of the theoretical section aims to present a comprehensive account of relevant theories regarding geographical agglomeration phenomenon. Starting with Marshallian industrial districts, industrial clusters and learning regions, concepts are discussed together with their arguments for agglomeration drivers. Respective critical reflections are provided when necessary (Sections 2.2.1, 2.2.2 and 2.2.3). The role of lead firms in regional agglomerations is a relevant topic for the research questions of this study, which is mostly neglected in literature. This topic is discussed in Section 2.2.4, followed by a comprehensive presentation of knowledge-intensive business services and their spatiality (Section 2.2.5).

The third major part of the theoretical section deals with technological and structural change processes. Section 2.3.1 deals with the long-waves of technological change discussions and consequently, the notions of path dependency and lock-in are presented within the context of the research questions on hand. Section 2.2.4 re-states the research questions, explains the explanatory model and lists the hypotheses derived from literature.

The empirical section presents a detailed account of research findings with relation to the theoretical background. It begins with a presentation of transformations in the automotive industry, providing the background for the regional phenomena this study aims to investigate (Section 4.1). The regional characteristics of Stuttgart are explained with the help of secondary resources in Section 4.2 and consequently the automotive cluster is introduced in Section 4.3. Section 4.4 serves two purposes; firstly it gives a detailed picture of software services for automotive industry in general and secondly, it describes the presence of these services in Stuttgart region.

An answer to the first research question is presented in Section 4.5 with the help of a discussion on the "user specification document" (in German: Lastenheft). The second research question is answered with the help of two separate but related sections. Section 4.6 gives a detailed account of the position of KIPS customers with respect to different technical and social issues and the following section 4.7 presents details on the position of software firms. This approach has been adopted to give due importance to the demand side of the discussion. Section 4.8 explains how lead firms affect their regional environment through strong demand side-effects in the knowledge-production context. Finally, Section 4.9 suggests cautiously-formulated arguments for the regional structural change discourse. The consequent summary section recapitulates the empirical findings against the research questions and offers suggestions for policy-making and research realms.

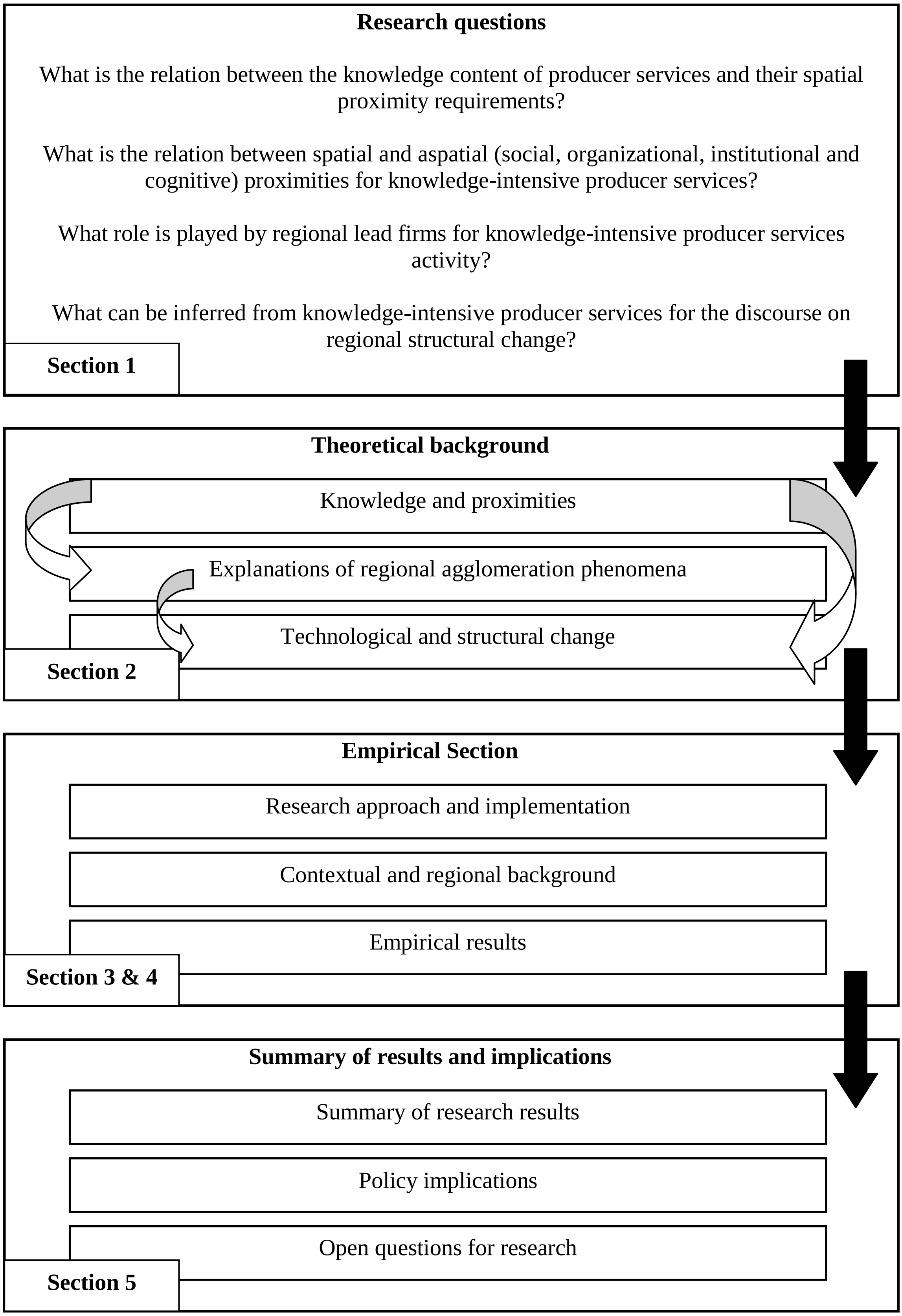

Fig. 1: Outline of the study

Source: Own representation

2. Theoretical background

2.1. On knowledge, its production and proximities

2.1.1. Information and knowledge

During the last decade, innovation, learning and knowledge have been embraced by the economic geography discourse and policy-making realm to explain different issues in post-industrial knowledge societies e.g. the raison d'être of regional agglomerations, regional competitiveness or effective regional policy-making (Giddens 1992 pp. 648-649, Malmberg/ Maskell 2002, Feldman 1994 p. 110, Porter 1998a pp. 552-556, OECD 1999). This study partly addresses the role of knowledge in business relations; however before starting with the discussion on knowledge-producing relations, it is necessary to underline the differences between the related constructs data, information and knowledge.

Despite their often interchangeable use in daily language, data[1] and information are slightly different in nature. In exact sciences for instance, data signifies "a measurement", which can eventually be processed into an organized, structured form to become information (Lambooy 2000 p. 18). Nonaka and Takeuchi state that information "provides a new point of view for interpreting events and objects, which makes visible previously invisible meanings or sheds light on unexpected connections" (1995 p. 58). In the same breath, they define knowledge as "a dynamic human process of justifying personal belief toward the truth" and state that "information is a flow of messages, while knowledge is created by that very flow of information, anchored in the beliefs and commitment of its holder." This connects with how Albrecht sees knowledge as a result of information processed by consciousness and how he defines it as 'understood information' (Albrecht in Eppler et al. 1999 p. 222). Considering the respective definitions mentioned here, the relations between data, information and knowledge can be sequenced as follows: "data is an ordered sequence of given items or events… information is a context-based arrangement of items whereby the relations between them are shown…and knowledge is the judgement of the significance of events and items, which comes from a particular context and/or theory" (Tsoukas/Vladimirou 2001 p. 976). Clearly, if the adding of order turns data into information, then information becomes knowledge when insight, abstractive value and better understanding are added and ultimately "knowledge is essentially related to human action" (Spiegler 2000 p. 8, Nonaka/Takeuchi 1995 pp. 58-59).

[1] Linguistically, data is a plural form of datum, which is originally a Latin noun meaning "something given." Today, data is often, but not necessarily always, used in English both as a plural and as a singular mass noun.

It is necessary to grasp the distinctive character of two types of knowledge, explicit and tacit knowledge, in order to find a way through the discourse on localized knowledge-production, innovation systems and learning regions literatures. Michael Polanyi came up with the epistemological concepts of tacit and explicit knowledge, based on the codifiability of knowledge in language and in other systematic representations (Polanyi 1966). As per definition, explicit (or codified) knowledge can be expressed as shared codes; hence it can be disembodied, stored, transferred and traded, which makes it an extremely crucial strategic source for the survival and well-being of a society (Giddens 1992 p. 648). However, what human beings can express in codes is only part of the entire body of knowledge they possess; as Polanyi famously wrote “We can know more than we can tell” (Polanyi 1966 p. 4). A significant amount of knowledge is stored in the habits, routines and subconscious of individuals and groups. Polanyi also likened the difference between explicit and tacit knowledge to the verbs “wissen” and “können” in German and referred to the notions of “knowing what” and “knowing how” described by the British philosopher Gilbert Ryle (ibid. p. 7). Economic geography literature on innovation and learning sees tacit knowledge to be personally developed, context-specific and hard-to-communicate in character. In comparison, codified information has a stable character across time and space, and it boasts a sharply decreasing marginal cost of exchange (Storper/Venables 2004 p. 47).

Compared to codified knowledge, tacit knowledge can display a higher friction to distance, in that it demands a more complex form of discourse from both the source and receiver of the message. Those who possess tacit knowledge face difficulties in formulating this into words for others, and receivers face comprehension difficulties with received messages due to mismatched codes of reference and discrepancies between respective knowledge bases. Thus, exchange of tacit knowledge often requires a dialogue of “interruption, repair, feedback and learning”, which can be carried out more efficiently through face-to-face (F2F) interaction (ibid.). Due to this need for F2F interactions, it has been claimed that the (re-)production of tacit knowledge can be stimulated and accommodated best by spatial proximity (Gertler 2003, Morgan 2004). This dimension will be discussed in more detail in the following sections.

Besides being, as it were, the hidden part of the human knowledge iceberg, tacit knowledge is also instrumental in dealing with uncertainty that is inherent to economic activity. Loasby writes, “if uncertainty is absent then every problem situation can be fully specified…and choice is reduced to a logical operation” (Loasby 2002 p. 1). In daily economic practice, uncertainty takes the form of unexpected situations that demand deeper resources and skills from actors than the mere ability to dig out pre-given answers in books or databanks. In addition, those involved are called upon to tap into their past experiences or, in other words, into their tacit knowledge reserves to devise the necessary solutions. Therefore tacit knowledge – in essence – supplements codified knowledge for a society's survival (Nonaka/Takeuchi 1995 p. 61).

The two types of knowledge feed each other by bilateral conversion processes, which occur through social interaction. Nonaka and Takeuchi offer elaborated definitions for the four stages of knowledge-conversion processes: socialization, externalization, internalization and combination. Socialization refers to the sharing and creation of tacit information, e.g. of shared mental models and technical skills. This process includes not only exchanges of codified information, but also observation, imitation and practice. The sharing of experiences stimulates learning-by-watching and learning-by-doing. Externalization is the process of "articulating tacit knowledge into explicit concepts" and, like internalization, goes to describe how tacit and explicit knowledge are interlinked and how they help each other accumulate (ibid., Nonaka 1994 p. 19).

The externalization of tacit knowledge in "language" can be performed with the assistance of metaphors, analogies, concepts hypotheses and models. These are utilized to create similar images in the minds of the message's sender and receiver through collective reflection and creation of higher levels of "commonness." Externalization is a critical process for the augmentation of knowledge. Combination involves combining different bodies of explicit knowledge to create new knowledge. This could take place through formal education or through such media as documents, meetings and IT-tools. Internalization is the process of transforming explicit knowledge into tacit knowledge, which includes the development and adoption of shared mental models and know-how in an enterprise by its members through learning. Learning-by-doing is a form of experiencing what others experienced and it can actually be complemented by codified information, e.g. documentation, which helps actors to re-experience others' experiences.

In the idealized case, these four processes take place in a sequence, which can be portrayed as a spiral (Fig. 2). The socialization process provides a field for interaction that facilitates the sharing of members' experiences and mental models. Then a "meaningful" dialogue (or collective reflection) begins to produce codified knowledge through an externalization process. Such externalized or, in other words, codified knowledge is combined with other knowledge by individuals to be augmented further. Finally, the internalization process occurs through learning-by-doing.

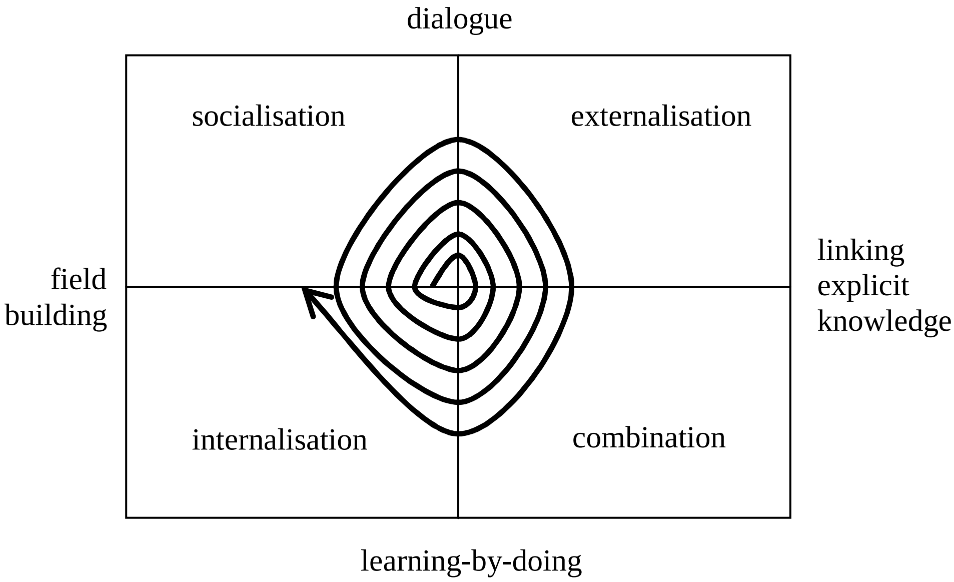

Fig. 2: Intra-firm knowledge-production spiral

Source: Nonaka/Takeuchi 1995 p. 71

Although they do express how they see the propagation of tacit-explicit knowledge conversion across ontological levels, Nonaka and Takeuchi pay relatively little attention to the inter-firm side of knowledge-production in comparison with their detailed account of intra-firm knowledge-production. The propagation of knowledge level up the ontological ranks begins with the mobilization of an individual's knowledge, which is socially and organizationally amplified through the four modes of knowledge conversion. This starts in departments, then crosses boundaries between departmental borders in a firm and eventually reaches outside the firm. As the interaction takes place on a larger scale, the amount of knowledge produced and the knowledge-production rate increase. Further details of the inter-firm dimension of knowledge-production will be discussed in more detail later in this chapter.

2.1.2. Knowledge-production and learning

Having defined the basic concepts and notions of knowledge, this section proceeds to knowledge-production or, as economic geography literature likes to say, to "learning." Almost simultaneously with post-Fordism discussions, when a new era of all-bearing political and economical uncertainty was manifesting itself, the presence of uncertainty in technological change began to be stressed more strongly by academics from economics and economic geography realms (Dosi 1988 p. 222). However, this time, unlike the previous views of Schumpeter I and II mould, which respectively put the emphasis on the central role of the entrepreneur and the large enterprise, the role of interaction and collaboration took centre stage (Malerba/Orsenigo 1996 p. 452, Dosi 1988, Lundvall 1988). During this period, a new wave of sweeping technological changes driven by the rise of microelectronics and ICT[2] was slowly taking over products and production processes making it increasingly difficult for enterprises to be solely dependent on internal knowledge resources. Clearly, the motto "if it ain't broke, don't fix it" did not apply to this environment of change, when services and processes needed continuous modification, improvement and re-creation. On this background, innovation came to be mentioned ever more often within economic context, boundaries between innovative and productive activities started to blur and new buzz-words such as "innovation-mediated production" entered economic geography vocabulary (Florida/Kenney 1993).

Innovation, whose literal meaning is "introduction of new practices or ideas"[3]," entails "the search for, and the discovery, experimentation, development, imitation and adoption of new products, new production processes and new organizational set-ups" (Dosi 1988 p. 222). The innovation process involves the production of knowledge by blending different categories of knowledge together and innovative activity is in essence the "craft of combination" (Elam 1993 in Lundvall/Johnson 1994 p. 30).

Decisions relating to innovative activities involve a selection process between various alternatives that are combined with irreversible investments (Newlands 2003 p. 525). The inherent uncertainty and complexity therein require resources and processes that can hardly be confined within the organizational and technical boundaries of a firm (Dodgson 1996 p. 285). Therefore, apart from helping overcome the problem of resource needs, contacts with and inputs from "others" can potentially increase the efficiency of decision-making and allocation processes. It follows that in order to sustain themselves firms require a degree of personal, intra- and inter-firm level interaction and cooperation (Storper 1989 p. 274, Lundvall/Johnson 1994 p. 25). On the horizontal dimension of these relations, firms with related and complimentary competencies and skill-sets come into contact in various ways, whereas the vertical dimension functions through (often transaction-based) user-supplier relations. The remainder of this section focuses on the latter, while the horizontal dimension is discussed within the context of regional agglomeration phenomena in Section 2.2.3.

From the neo-classical view of economic practice, inter-firm transactions take place in idealized "pure markets", where closer and prolonged client-supplier relations are deviations from the norm. The pure market notion focuses on the optimum allocation of resources but it

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[2] ICT: Information and communication technologies.

[3] The New Penguin English Dictionary (2000), first edition.

fails to account for the economic relations involving innovation and knowledge-production (Lundvall/Johnson 1994 pp. 33-35). The efficiency of these relations depends on the mutual knowledge of user needs and the use-value of technical opportunities. Producers and users separated by a market cannot exchange knowledge signals because they could do little more than exchange information on existing products and price/volume signals (Lundvall 1988 p. 350). However in real living economies, firms do engage in and interact through “impure” relations that are long-lasting and in effect “quasi-integrated”, although transacting parties remain two legally independent entities (Granovetter 1985 p. 497).

Knowledge-producing and innovative user-producer interactions involve opportunities and risks for both sides. For the producer, customer needs and capabilities offer both insights and incentives, and the knowledge gathered by learning-by-doing offers significant potentials. On the other side, users require exact knowledge about new products relating to their specific needs and the assistance of the producer to maximize its gain from purchased solutions (Lundvall 1988 pp. 352-353). However, there are considerable risks for both sides relating to loosing critical firm specific knowledge and know-how to outside parties. Therefore, in order for the transacting parties to be convinced that the information that they share is not lost, but on the contrary is an investment. Therefore, trust is also an important factor as it enables and eases the exchange of information between parties (Asheim 1996). Once a trust-based mutual understanding has been established, the enterprises begin to use their relations with their customers and suppliers as sources of knowledge and learning (Håkansson 1987 pp. 94-95, OECD 1999 p. 225).

In the definition they suggest for learning, which has largely been adapted by subsequent learning regions literature, Lundvall and Johnson refer to “those processes which lead to new knowledge and to those which spread old knowledge to new persons” (Lundvall and Johnson 1994 p. 23). Hence, while its meaning in daily use refers to “gaining knowledge of or skill in (something)”[4], in Lundvall and Johnson’s version the act of learning also involves the production of new knowledge. As such, it causes a slight but not insignificant confusion. This study refers to knowledge-production as well as to learning (as in learning from a source) and interactive learning (learning from each other) separately in order to differentiate between the three.

Learning activities can be divided into two groups: intentional learning (education, training, R&D etc.) and learning as a by-product of other activities. The latter takes several forms.

[4] The New Penguin English Dictionary (2000), first edition.

Learning-by-doing is stimulated by repetition and improvement of a task, while ‘learning-by-using’ emanates from adopting and adjusting practices from elsewhere (e.g. a just-in-time system). Firms also ‘learn by interaction’ when they develop teams of experts who can create knowledge interactively with counterparts inside and outside the company (ibid. 32, Cooke 1998 pp. 12-13). Interactive learning takes place at various interfaces inside and outside the enterprise, thereby also in inter-firm relations.

Perhaps as an ironic gesture to neoclassical economists, Håkansson and Johanson define *business relationships* as “close, long-lasting, exchange relationships between supplier firms and customer firms” (Håkansson/Johanson 2001 pp. 2-6). The authors continue to break down the interactive learning process in business relationships into three phases. During the first, firms interactively identify and approve each other’s willingness and ability to continue doing business together, which consequently leads to lower transaction costs and increased interdependence among parties. The second phase includes firms modifying their routines, which may lead to highly interdependent processes that increase the value of their relationship. This results in positive sum gains and shared outcomes for both sides (Dodgson 1996 p. 286). These advantages of interactive learning result from comparing, contrasting and combining a disparate knowledge basis and developing new knowledge. The interlinked production of tacit and codified knowledge includes intra-firm socialization, externalization, combination and internationalization phases and essentially “what is learned is profoundly connected to the conditions in which it is learned” (Section 2.1.1, Brown/Duguid 1991 p. 48). The third phase of interactive learning in a business relationship includes repeated interactions that lead to the long-term coordination of the activities between parties. Håkansson and Johanson also state that these relations may even create a state of quasi-organization, in which certain activities in and between the two firms are more closely coordinated with each other than the firms’ other activities (2001 pp. 2-6). Again, this recalls the notions of “quasi-integration” and “vertical near integration”, which refer to relatively stable relationships and the extension of sub-contracting relations to include deeper contents (e.g. design, development, marketing etc.) in a form that combines elements of vertical integration and disintegration in collaborative action (Granovetter 1985 p. 497, Leborgne/Lipietz 1991 pp. 38-39, Asheim 2000 p. 13). In terms of innovation, closer business relations provide firms with lower risks, scope, scale and speed economies (Love/Roper 2001 pp. 320-321). Therefore in order for supply relations to produce innovation returns, they must contain a degree of mutual trust that provides the incentives to adapt an open approach (Sako 1996 pp. 270-272).

2.1.3.Aspatial forms of proximity

Many of the stylized models in economic geography literature are in essence investigations into spatial proximity and its economic meaning. Recently, researchers have shown an increasing interest in the interrelation between aspatial and spatial proximities and the role of the former on the localisation of economic activity. The following pages present a summary of these efforts and theoretical constructs.

Dissecting proximity

The "Proximity Dynamics" research group of France, originally formed by industrial academics interested in space, was the first group of scholars to delve into aspatial forms of proximity (Torre/Gilly 2000 p. 170). Their inquiry starts by analyzing organizational proximity as a distinct element from geographical proximity and they explain it with the help of two notions: adherence and similarity. According to adherence logic, "actors close in organizational terms belong to the same space of relations (firms, networks…)", where they engage in interactions of various kinds (ibid. p. 174). The effectiveness of the coordination function embedded in these relations effectively co-produces the organizational proximity. Similarity logic underlines the causality between similarity of actors and shared organizational structures. The similarity of actors as such depends on shared reference spaces, knowledge and common institutional structures. These two notions do not foreclose each other; hence actors from the same intra-firm relational space can also share the same knowledge space.

Lemarié et al. (2001 p. 68) defines concepts with similar content by using the terms affiliation and similitude. While the logic of affiliation argues that actors belonging to the same area of relations (firm, network…) are close in organizational terms; similitude logic states that actors resemble each other, i.e. those who share areas of reference and knowledge are close in organizational terms. For the former, effectiveness of coordination is at the centre whereas for the latter, resemblance of representations and modes of functioning play the leading roles. Like Torre and Gilly, Lemarié et al. accede that these two dimensions of organizational proximity can coexist.

It is necessary at this point to remember that organizational proximity is also discussed elsewhere in literature within an intra-firm relations context. Loasby, who is from the Schumpeterian institutional economics school, states: 'it is required to promote compatibility within a group… by encouraging or imposing connecting principles [i.e., a corporate culture] which will guide, not merely choices, but the concepts to be used in framing problems'

(Loasby 1996 p. 49). The compatibility created through connecting principles actually translates easily into an intra-organizational proximity, which, according to Arrow, functions as sets of principles and codes that ease the conveying of information within an enterprise (Arrow 1984 p. 177). Arrow also states that “the need for codes that are mutually understandable within the organization imposes a uniformity requirement on the behaviour of the participants” (ibid. p. 179). Hence, the definitions of Loasby and Arrow actually conjure up the adherence / similarity and affiliation / similitude concepts, because the employees of an enterprise are bounded by relations of affiliation and their intra-firm relationships function with ease if and when they share a basis of behaviour and knowledge.

Proximity Dynamics discusses the cultural dimension of proximity under a relational proximity tag. Blanc and Sierra define it as a form of informal organization in and between firms or, in other terms, as non-economic relationships embedded in an economic environment (Blanc/Sierra 1999 p. 197). This includes a common language, culture, working ethics, mutual knowledge and trust, and usually respected norms of behaviour. Beside their claim that organizational proximity is formal against the informal nature of relational proximity, Blanc and Sierra introduce institutional proximity as a combination of organizational and relational dimensions. Coenen et al. (2003 p. 19) define relational proximity as a combination of societal (language, institutional and cultural settings) and cognitive factors (e.g. a technological knowledge basis) (Coenen et al. 2003 p. 19). While doing this, they also refer to both adherence and similarity dimensions as do Torre and Gilly.

Torre and Rallet suggest yet another combination of adherence and similarity dimensions of proximity in the construct “organized proximity”, which is the “ability of an organization to make its members interact” (2005 p. 49). In this context, organization serves to “designate any structured unit of relations. It might take any form of structure, e.g. a firm, an administration, a social network, a community and a milieu” (ibid.). Members of an organization are “close to each other because they interact” and explicit and implicit rules govern their interactions with the help of routines of behaviour (ibid. pp. 49-50). Nevertheless, it is a slight overstatement to claim that interaction suffices for “closeness.”

The organized proximity concept has its second dimension in the logic of similarity. Here, it is claimed that members of an organization share a system of representations, beliefs and knowledge and that the logic of belonging and similarity are complementary and partly substitutable – complementary because the belief systems limit the space for interpreting formal rules, thus increasing their effectiveness, and substitutable because of the way shared behavioural cohesion can make up for the lack of explicit ruling.

On this background, Boschma (2005) manages to devise a representation of micro-level proximity dynamics in a fashion that surpasses previous efforts in conceptual clarity. He analyses the proximity question along cognitive, organizational, social, institutional and geographical dimensions and furthermore, introduces a concern for the balancing effect of "distance" along each of these proximity axes. Thus, he argues that for a learning-based interaction to emerge and be sustained there must be a balance between proximity and distance.

Cognitive proximity

Enterprise knowledge-production and innovation are cumulative outcomes of internal resources and processes combined with external relations, for which tacit knowledge and skills are indispensable (Oerlemans et al. 2000 pp. 138-139, Bathelt et al. 2004 p. 34, Nonaka/Takeuchi 1995 p. 8). Partly due to the division of labour, the distribution of knowledge among enterprises (even within a single industry) varies vastly and considering inter-industry deviations it is safe to state that cognitive base and knowledge absorption capacity differ markedly across firms (Loasby 1998 p. 142, Boschma 2005 p. 63). Knowledge creation and learning often require combining these diverse capacities across the economic landscape, thereby necessitating firms to interact in order to identify, interpret and exploit new knowledge (Oerlemans et al. 2000 pp. 139-140, Håkansson/Johanson 2001). Validating whether a new piece of knowledge is fit for purpose is beset with unpredictability and therewith is as challenging as overcoming knowledge disparities (Dosi 1988 p. 222, Metcalfe/Ramlogan 2004 p. 660). These conditions require economic actors to maintain sets of technical and market-oriented competencies to filter out knowledge inputs. The lower the level of his or her competency, the higher the cost for an actor to find, comprehend and absorb the knowledge needed (Perez/Soete 1988 pp. 465-470). For interactive relations, if the cognitive distance is too great it is technically impractical and economically impossible for two parties to engage in a knowledge-based relationship. Hence, cognitive proximity, a shared knowledge base and the expertise that allows learning relations are crucial for knowledge exchanges and knowledge-production between actors (Boschma 2005 p. 63). Elsewhere, technological proximity is defined in a similar vein to express "what actors exchange in interactions and the potential value of these exchanges" (Knoben/Oerlemans 2006 pp. 77-78). In comparison, the cognitive proximity notion is slightly broader as it contains references to “how” actors interact and is therefore a more effective tool to analyze interactive learning relations across unrelated knowledge bases.

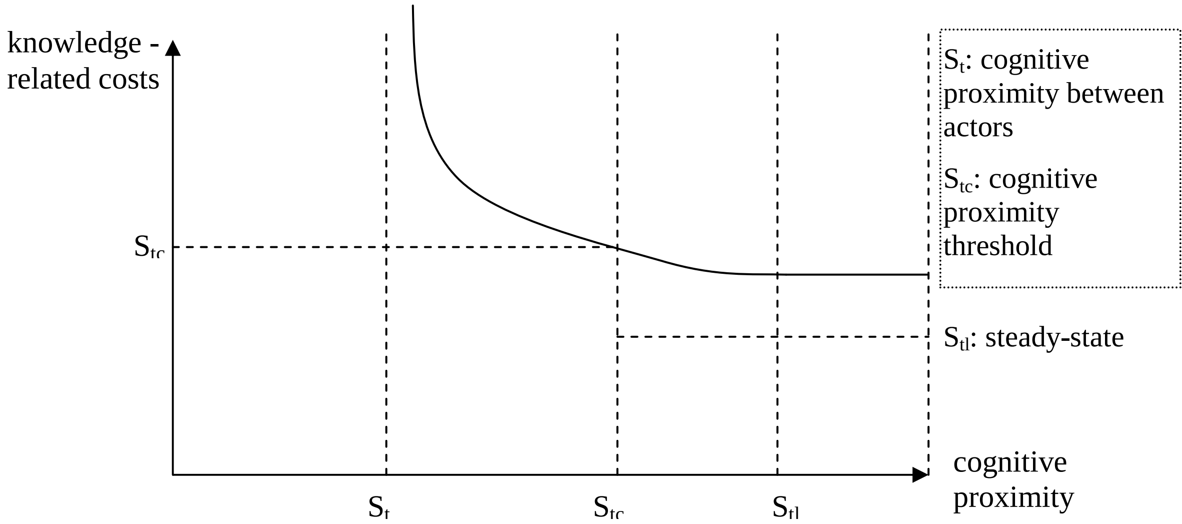

Fig. 3: Variation of knowledge-related costs vs. cognitive proximity of partners

Source: Perez/Soete 1988 p. 467

Fig. 3 is a derivative of Perez and Soete’s representation of the variation of knowledge acquisition costs for one of the partners in a knowledge-incorporating exchange with another (Perez/Soete 1988 p. 467). These costs are highest when cognitive proximity between partners is lowest, and indeed there is a proximity threshold (S_t) below which the cost of knowledge acquisition is infinitely high. As the cognitive gap between partners closes, the knowledge acquisition costs drop accordingly and after a certain level of cognitive proximity (S_{t1}), a steady-state is reached as knowledge exchanges take place within routine business exchanges with minimum additional effort required for knowledge acquisition.

Nevertheless, this is not meant to imply “the closer, the better.” Boschma lists three reasons why a certain degree of cognitive distance is necessary for learning relations to emerge and to endure. To begin with, dissimilar bodies of knowledge are the basic precondition for knowledge exchanges and creativity, although they are subject to ceilings as explained above (Bathelt et al. 2004 p. 36). Secondly, low cognitive proximity can potentially turn into a cognitive lock-in, as actors may loose their capacity to identify and respond to new knowledge (Boschma 2005 p. 64). The routines that emerge from the adopted knowledge basis can turn into what Levitt and March call a “competency trap” that “can occur when favourable performance with an inferior procedure leads an organization to accumulate more experience with it, thus keeping experience with a superior procedure inadequate to make it rewarding to use” (1988 p. 322). Thirdly, cognitive proximity increases the real and perceived risk of involuntary spillovers, which can have adverse effects in terms of competition and can indirectly cause distrust between enterprises, thus hindering communication.

Hence, a degree of cognitive distance should accompany cognitive proximity in order to avoid lock-in situations in learning relations. Noteboom states that “a trade-off needs to be made between cognitive distance, for the sake of novelty, and cognitive proximity, for the sake of efficient absorption. Information is useless if it is not new, but it is also useless if it is so new that it cannot be understood” (Noteboom 2000 p. 153 in Boschma 2005 p. 64).

Social proximity

The concept of social proximity has its origins in the notion of embeddedness, which stresses that economic relations are co-shaped by social context (Granovetter 1985). In Boschma’s model, social proximity refers to trust-based relations at the micro level supported by friendship, kinship and experience (Boschma 2005 p. 66). In doing so, Boschma leaves the influences of values, i.e. of ethnic and religious type, to the next sub-topic institutional proximity. His definition is also narrower than what Blanc and Sierra call relational proximity, which covers non-economic relationships by addressing common working ethos, language, culture and norms of behaviour (Blanc/Sierra 1999 p. 197).

Nonaka and Takeuchi state that “tacit knowledge” is actually contained in individuals rather than firms; hence social proximity between persons has to be established before tacit knowledge can be exchanged and mutually understood (Nonaka/Takeuchi 1995 p. 225, Metcalfe/Ramlogan 2004 p. 672). Social proximity is crucial for tacit-knowledge exchanges that can hardly take place in pro-market environments, where calculative and cost-optimising rationality persists. Besides, social proximity reduces opportunistic behaviour to a certain extent, because of the way it is based on committed relations between sides. To sum up, social proximity is a crucial element that helps actors at micro-level to manage dynamic learning relations effectively. Elsewhere in literature, this notion is expressed with reference to “relational and cultural proximities”, which overlap content-wise with Boschma’s account (Zeller 2004 p. 84, Coenen et al. 2003 p. 19, Blanc/Sierra 1999 p. 197).

On the other side, Boschma mentions two main negative effects of too much social proximity. Firstly, he refers to Uzzi’s argument that asymmetrical approaches between actors to social proximity may cause some of them to underestimate the potential opportunistic behaviour in markets (Boschma 2005 p. 66). Secondly, on the long-term, social proximity may lead to rigidities that prevent actors from considering and adopting new ideas and ways of doing.

Moreover, based on Uzzi's model, Boschma suggests the following graph to depict the relationship between innovative performance and embeddedness (Fig. 4).

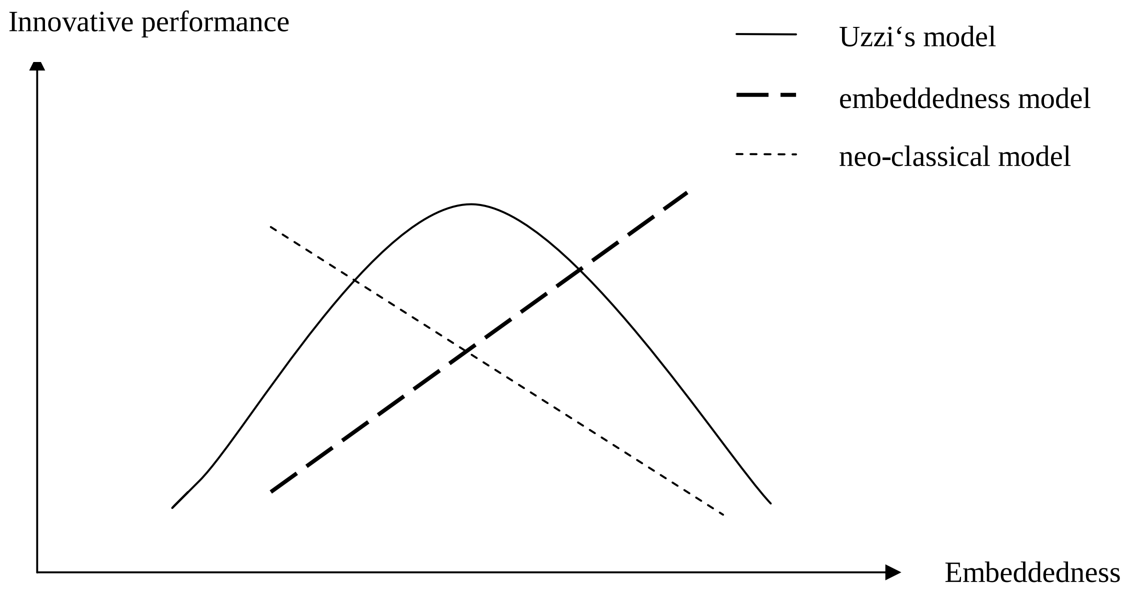

Fig. 4: Relationship between the degree of embeddedness and innovative performance of an enterprise.

Source: Boschma 2005 p. 67

This inverted-U relationship between the degree of embeddedness and innovative performance of an enterprise suggests that social proximity has a positive effect on innovative performance in economic relations to a certain point after which the sides become too closely tied and innovativeness deteriorates. This also partly reflects the "weakness of strong/strength of weak ties" notions of Granovetter and Grabher as well (Granovetter 1973, Grabher 1993 pp. 255-277).

Organizational proximity

Knowledge creation involves, among other actions, the exchange of complementary pieces of knowledge owned by different actors within and between organizations and these exchanges require a form of coordination. Various forms of governance can carry out the coordination function, like markets, firms and networks. These constructs differ with respect to "the degree of autonomy of exchange partners and the extent to which control over knowledge flows can be exerted" (Boschma 2005 p. 65).

Elsewhere in literature, part of which has been presented in the preceding pages, organizational proximity is often treated as a broad category that includes elements of cognitive character. Boschma removes the cognitive dimension out for analytical clarity and defines organizational proximity as “the extent to which relations are shared in an organizational arrangement, either within or between organizations” (ibid.). This is defined as a quasi-continuum of autonomy/control in organizational arrangements that span from the low proximity of independent actors, e.g. some spot electricity markets, to the close organizational proximity of hierarchically organised enterprises.

Organizational proximity provides the governance and control functions that help to avoid the uncertainty and opportunism that may arise in knowledge-producing relations (Storper 1989 p. 274, Gertler 2003 p. 85). Certain formal institutions, like intellectual property regulations, ensure returns for owners of new knowledge, yet their application entails high transaction costs and they are often restraining, unsuitable and slow. The mutually understandable codes of conduct suggested by Arrow are an alternative form of coordination in internal and external interactions and are capable of providing organizational proximity (Arrow 1984, p. 177). In this context, if cognitive proximity is providing tools regarding the contents of interactions and ways of selecting potential partners for interaction, organizational proximity deals with the process of interacting (Torre/Gilly 2000 p. 174). External relations are critical as firms rarely possess all the resources necessary to innovate, and organizational proximity provides a platform for the interaction of heterogeneous actors and resources (Oerlemans/Meeus 2005 p. 94).

Nevertheless, as in the case of cognitive proximity, being too close organizationally can also be detrimental to knowledge-production. Different sizes and levels of power of partners may lead to asymmetrical relations that cause impediments. These include a high-dependency on relation-specific investments, developing an inward-looking view on matters and a hierarchical structure that hinders feedback mechanisms. Because of the latter, new ideas cannot be communicated or rewarded and interactive learning comes to be stifled. Besides, high proximity structures may lack the flexibility to accommodate innovation-related changes that can potentially undermine the vested-interests in organizations.

Institutional Proximity

As previously mentioned in the pages on social proximity, Boschma’s concept places macro-level effects on business relations, such as norms and values of conduct, under the institutional proximity banner. Institutional arrangements at the micro-level, where norms and values are embodied in specific exchange arrangements, are covered by social and organizational proximity notions. In their proximity concept, Blanc and Sierra define institutional proximity in a similar essence, namely as the combination of organizational and relational proximities (Blanc/Sierra 1999 p. 197).

Institutions can be formal (e.g. language and a legal system that rules ownership rights) and informal (i.e. values of conduct), and they jointly influence social and economic behaviour (Coenen et al. 2003 p. 7). Practically, they act as ‘glue’ for collective action by reducing uncertainty and transaction costs. Without institutional proximity the actors would lack the necessary social cohesion and common boundaries. Institutional proximity is, as it were, the ground beneath other proximities that have been discussed to this point and as such it co-defines the mechanisms of knowledge sharing and interactive learning (Boschma 2005 p. 68). However, the interdependent nature of institutions can potentially cause inflexibilities and inertia. The change in one element of an institutional system can cause instability, as it can trigger alterations in the relative positions of others; besides, the vested interests of actors and groups can result in further rigidities in the system. Therefore, an institutional system can turn inward and reject change and adaptation. In this sense, it resembles a lock-in situation, where new ideas and innovations would have difficulty to become adapted.

Boschma’s concept offers a powerful tool and despite primarily addressing the inter-firm interaction realm, “proximities” can also be implemented to intra-firm issues such as “dealing with distance on R&D work” in a global enterprise (Grinter et al. 1999 p. 313).

2.1.4. Geographical reflections on aspatial proximities

In its basic meaning, geographical proximity is the distance between points in physical space. As an alternative, Torre and Gilly suggest using the term functional proximity, which is more oriented towards daily practice as it regards socially-constructed aspects like transport infrastructure and financial means, together with the judgmental part of perceiving geographical distances (Torre/Gilly 2000 p. 174, Torre/Rallet 2005 p. 49). The availability of transport infrastructure changes travel times; and the concept of what is near and what is not can vary according to age, social background, gender and profession. For the purposes of this study, the functional aspect of geographical proximity is referred to when spatial proximity is mentioned.

Economic geography literature deals with the aspects related to social, organizational and institutional proximities often within the context of social capital. One of the early proponents of this term in Anglo-Saxon literature was Putnam, who defined it as “those features of social life – networks, norms and trust – that enable participants to act more effectively to pursue shared objectives” (Putnam 1996 in McLean et al. 2002 p. 7). Further descriptions have been offered by economic geographers: “various features of the social organization of a region, such as the presence of shared norms and values that facilitate coordination and cooperation among individuals, firms, and sectors for their mutual advantage” (Wolfe 2002 p. 10) or “the norms and networks facilitating collective action for mutual benefit” (Woolcock 1998 p. 155).

Certain elements of social capital, e.g. shared norms and values, facilitate organizational and institutional proximities. In comparison to Putnam’s social capital definition, Boschma’s social proximity notion refers to a smaller realm, encompassing socially embedded relations at the micro-level that are based on friendship, kinship and experience. These are built up through repeated interaction and hence, geographical proximity could be a stimulant factor because shorter spatial distances create favourable conditions for social interaction, informal relationships and trust building (Boschma 2005 p. 67 and 70). In learning regions literature itself, social capital is primarily interpreted as a product of history at spatial proximity (Asheim 2000 p. 16, Malmberg/Maskell 2002 p. 441).

However, even without permanent spatial proximity, repeated interactions can take place and stimulate the development of context dependent networks of practice, e.g. ‘epistemic communities’ (Håkansson 2005) or ‘communities of practice’ (Gertler 2003 p. 86). These networks contain elements of cognitive and social proximities, but they are not necessarily localized. After all, a network is a social construct that has its own definition for ‘outsiders’, whether or not these are co-located (Amin/Cohendet 2005 p. 469). That is to say, social capital is clearly collaboratively created, but it is neither a direct product of spatial proximity, nor does it have to be territorially contained as a rule. Indeed, while collaboratively produced aspatial social capital can substitute for geographical proximity, the latter cannot compensate for the lack of the former (Coenen et al. 2005 p. 28). Therefore, social capital can be created and sustained over geographical distance when the shared incentives are strong enough, but spatial proximity alone cannot induce social capital.

“Learning regions” literature[5] builds on the “immobility” of tacit knowledge, which is claimed to be shareable only through face-to-face interaction in environments of common language, ‘codes’ of communication, conventions, norms and past experiences (Gertler 2003 p. 84). In a way, the learning regions discourse refers to social, organizational and institutional proximities in all but the name. The shortcoming of the learning regions discourse is the overbearing importance given to geographical proximity. On the other hand,

[5] Learning regions are locations that “provide a series of related infrastructures which can facilitate the flow of knowledge, ideas and learning” (Florida 1995 p. 532). A more detailed discussion follows in Section 2.3.3.

temporary geographical proximity matched with cognitive and social proximities can substitute the need for firms and individuals to co-locate permanently (Torre/Rallet 2005). In fact, its impact is more subtle and indirect in that it can assist the construction and strengthening of other proximities, which are direct enablers of knowledge-producing relations (Howells 2002 p. 874, Boschma 2005 p. 70, Rallet and Torre 1999 p. 375).

Nevertheless, conditions and opportunities provided by a dynamic cluster can potentially create an environment where efficient management of different proximities and risks of lock-in are possible[6] (Dosi 1988 p. 222, Boschma 2005 p. 72). The requirement of proximity management at firm level and its governance at the macro-level can be achieved with a degree of convenience at permanent spatial proximity, largely due to easier face-to-face contacts that help modulation and coordination mechanisms (Storper/Venables 2004 p. 62). Indeed, a cluster as described by Porter could strike a balance between social proximity and distance as it pits cooperation and rivalry against each other on the regional level (Porter 1998a p. 103 and 117). As such, a cluster environment coincides closely with the solution offered by Uzzi for potential lock-in situations (Uzzi 1997 in Boschma 2005 p. 67).

2.2. On regional agglomeration phenomena

2.2.1. Marshallian theories on regional agglomeration

Alfred Marshall's writings on the "industrial districts" of industrialized Great Britain in the late 19th and early 20th centuries provided elements to most theorizations in Anglo-Saxon literature on regional agglomeration phenomenon (Marshall 1925 [1890] pp. 267-277). Marshall himself listed three factors as chief reasons for the "concentration of specialized industries in particular localities": labour-market pooling, specialized input-output transactions and localized technological externalities. Smaller firms can develop a more natural and intimate grasp of their trade (and hence specialize) and can profit from the knowledge externalities of their location through publications, personal contacts and interaction. Therefore with these externality effects, an industrial district offers a "competitive alternative" to a large enterprise (ibid. pp. 284-285, Asheim 2000 p. 415).

Marshall claimed that districts composed of a large number of small enterprises provided an alternative industrial form to the internal economies of big companies (ibid. p. 277). He coined the term "external economies" for the advantages derived from the concentration of an industry on a certain location: "the economies arising from an increase in the scale of

[6] Supporting evidence for the existence of intra-regional knowledge creating relations is available in literature, for instance in Sternberg's study of three German regions (Sternberg 1999 p. 533 - 534).

production of any kind of goods,…fell into two classes – those dependant on the general development of industry and those dependent on the resources of the individual houses of business engaged in it and the efficiency of their management; that is into *external* and *internal* economies" (Marshall 1925 p. 314, emphasis in original).

Labour pooling is primarily based on the reciprocal and seemingly self-sustaining relation between the interests and convenience of employers and employees: employers set up shop in locations where there is a broad choice of the skilled labour they require, and in return those who seek jobs move to locations where their skills are sought by employers. Marshall himself wrote: "When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighbourhood to one another. … Again, in all but the earliest stages of economic development a localized industry gains a great advantage from the fact that it offers a constant market for skill. Employers are apt to resort to any place where they are likely to find a good choice of workers with the special skill which they require; while men seeking employment naturally go to places where there are many employers who need such skill as theirs and where therefore it is likely to find a good market" (Marshall 1925, p. 271). This naturally reduces the risks involved for both sides arising from adverse or unexpected situations. Employees have a higher chance to find a new or better job, should they need or wish to look for one and companies can achieve better job-matching for vacancies that require specialized skilled with relative ease in an industrial district, as compared to an isolated location (Krugman 1991 p. 40, Newlands 2003 p. 522).

As for specialized input-output relations, these are meant to refer to the social division of labour that builds on technical labour. As opposed to a big firm where all the production means are owned by a single entity or authority, smaller capitalists in a district own the necessary means for smaller branches of the production process. Marshall writes "…advantages of production on large scale can in general be as well attained by the aggregation of a large number of masters into one district as by the erection of a few large works… it is possible to divide the process of production into several stages, each of which can be performed with the maximum of economy in a small establishment" (Marshall in Whitaker 1975 p. 196). Thanks to the extensive division of labour, these machines can be used at high capacity and economically, therefore even though they might be costly to purchase or maintain smaller enterprises can still afford them. Marshall also implies that supporting industries develop in and around industrial districts, further bolstering its character as a system (Marshall 1925 p. 271). Through all these effects, internal and external economies interact in a mutually reinforcing fashion, namely, the specialized firms that produce the intermediary inputs for the final manufacturer operate at higher capacity, thus reaching internal economies easier. On the other hand, the final manufacturer is able to maintain a smaller operational size, thereby avoiding the management complexity that would ultimately undermine the flexibility of its operations (Hoover 1971 p. 78).

Thirdly, Marshall argues that specialized technological knowledge is diffused and reproduced locally in industrial districts. In one of his probably most quoted lines, he wrote “The mysteries of the trade become no mysteries; but are as it were in the air,…Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further ideas.” (Marshall 1925 p. 271). By this, he suggests several points: the social dimension of business in general and the innovativeness and interactive production of knowledge in particular as well as the seed of incremental innovation concepts and a localized technological culture that reproduces itself. This is naturally a far cry from the concept of a profit-maximizing enterprise portrayed in the neo-classical economic theory and views cultural proximity as a corollary to localisation (Asheim 2000 p. 416).

Localisation and urbanisation

Localisation economies stem from the agglomeration of firms from a single same industry or sector on a single location, where cost savings can be achieved through more efficient transactions by spatial clustering (Hoover in Isard 1956 p. 172, Knox/Agnew 1998 p. 250). Due to shared problems, issues and means, among a group of agglomerated firms with same or similar interests, technological externalities and scale economies for inputs can come into being. These benefits are passed on to customers and/or users and in return create advantages for their producers (Harrison et al. 1996 p. 236). Furthermore, Storper suggests that the availability of suppliers from same or related industries allows firms to be able choose what to do internally and what to outsource, and this phenomenon eventually becomes a driver for the regional division of labour (Storper 1997 pp. 43-44).

The other variation of localized external economies is urbanisation, which is “for all firms in all industries at a single location, consequent upon the enlargement of the total economic size (population, income, output and wealth) of that location, for all industries taken together” (Hoover in Isard 1956 p. 172). The degree of vertical and horizontal division of labour in urban locations is much more extensive than elsewhere, and as such their strength comes from the diversity of skills, interests and resources (Jacobs 1961). Urban locations often offer transaction cost advantages for dynamic industries for which conditions and markets change swiftly; and the increased personal trust based on social proximity stimulated by spatial agglomeration helps to handle these changes more efficiently. Firms can compare alternatives easier and faster, for instance when it comes to choices among suppliers or “make or buy” decisions. On a different note, cities also often offer sophisticated pools of services industries and attract higher skilled employees, who choose to stay near the rich employment opportunities and social amenities of the urban locations (Storper/Walker 1989 pp. 139-142).

Marshallian Industrial Districts

An important concept, which literally stemmed from Marshall’s work on English locations, was launched in Italy in the late 70’s: industrial districts. The core ideas of these discussions were introduced to the English speaking readership in Piore and Sabel’s book “Second Industrial Divide” (Piore/Sabel 1984). Initially the analyses and discussions focused on the agglomerations of textile and machinery industries in the centre and North-East of Italy, areas which he called “the third Italy” (Brusco 1990 pp. 13-16). Afterwards certain other locations, including Baden-Württemberg in Germany, attracted attention within the context of industrial districts discussions (Schmitz 1992 p. 88).

It was claimed that the vertically-integrated corporation was an inflexible organizational form that could not deal with the new, interaction-oriented, fiercely competitive world of capitalism and its ever-volatile tastes and demands (Harrison 1991 p. 471). It was also suggested that the alternative to a mass-producing Fordist firm was a smaller enterprise with flexible labour and (then) new flexible manufacturing technologies. These technologies: (1) allowed smaller batch production by smaller firms without loosing much on efficiency, (2) changed the focus from economies of scale to economies of scope, which (3) enabled firms to deal with rapid changes in demand without incurring high losses or reductions productivity (Amin 1994 p. 15, Dunford/Benko 1991 pp. 289-290). The agglomeration of flexibly specialized firms on locations with shared a social fabric was seen as a solution to the coordination needs arising from the extended social division of labour (Sengenberger/Pyke 1992 p. 15 and 19).

The spatially concentrated division of labour and external economies derived thereof in Italian industrial districts reminded strongly of Marshall’s notion of industrial districts of the late 19th century England, which led to the name “Marshallian industrial district” (Storper 1997 p. 5, Amin/Robins 1990 p. 195). The increasing employment and growth figures of smaller enterprises were seen as proof of the increasing functional and organizational fragmentation of economic activity in the developed west; and the economic success of Third Italy at the time led academics to embrace the Marshallian industrial district concept as an explanation of and model for the times (Loveman/Sengenberger 1990 8-20, Sengenberger and Pyke 1992 pp. 7-11, Becattini 1990a).

The extensive literature on industrial district suggests a variety of definitions and characteristics for industrial districts: “spatially agglomerated production complexes together with their dependent labour markets and intercalated human communities” (Scott 1988, in Amin/Robins 1990 p. 192); [districts eschew price-competition by] “…using flexible machines and skilled workers to make semi-custom goods that command an affordable premium in the market” (Sabel 1994 p. 106) and “a socio-territorial entity which is characterized by the active presence of both a community of people and a population of firms in one naturally and historically bounded area” (Becattini 1990 p. 38). These three examples summarize the central notions: spatial proximity, closely bonded labour markets and the social and historical dimensions. Brusco provides a definition according to the size of the enterprises, which is, as most of the literature states, small to medium sized, and the district itself is described as follows:”...industrial district is a small area… and [with] around 1000 to 3000 firms with fewer than 20 employees” (Brusco 1990 p. 14). However, Scott leaves the firm size out of his definition of industrial district: “a localized network of producers bound together in a social division of labour, in association with the necessary labour market” (Scott 1992 pp. 266-267). As an explanation, he declares that the mix of establishment would be case-dependant, and larger enterprises can indeed stimulate the agglomeration of small enterprises, unless they stifle competition or monopolize innovation thus forcing a vertical integration.

The characteristics of economic relations of an industrial district can thus be summarized as follows (Garofoli 1991 in Asheim 2000 p. 418):

- an extensive division of labour between firms that leads to a dense network of inter and intra-sectoral input-output relations.
- strong product and production labour at the firm and plant level that limits the spectrum of activities, stimulates development and acquisition of specialized knowledge, facilitates the introduction of new technologies, thereby increasing the mutual dependency between the firm and the subsystems in the economic area.
- effective information networks at the district level that form the basis for rapid and broad circulation of information on markets, products, new and alternative

technologies, experiences made from trials, new financial and commercial knowledge, which ultimately transforms the individual packets of knowledge into a common property of the industrial district. Face-to-face contacts facilitated by geographical proximity, especially between the suppliers and users of goods and services, lead to a cascade effect in the transmission of technological and organizational improvements through the system of firms, that ultimately increases the efficiency of the local system.

- highly competent local workforce, partly due to inter-generational transfer of knowledge of products and processes and partly due to existing training possibilities from technical schools and institutions.

The networks, which can also link to outside of the district, are crucial for the firms to identify and adapt to changes in the market (Alberti 2006). The ownership was reported to be fragmented, but trust-based social relations and family networks filled in for the missing centralized control functions (Lorenz 1992 pp. 198-200, Sengenberger/Pyke 1992 p. 19). Although, compared to these early accounts on industrial districts, recent authors report divergent histories for different districts and claim that permanent vertical structures and "groupification" of enterprises have been formed (Nuti 2004 p. 71, Brioschi et al. 2004 pp. 167-172).

Sub-contracting relations, competition and cooperation are the primary mechanism of deepening skills and the knowledge-base of individuals and firms through labour. Firstly, the firms at the same stage(s) of the processes learn from each other through imitation-competition and secondly, firms belonging to different or adjacent stages of the process learn through interaction (Cainelli/De Liso 2004 p. 245). Mutual knowledge of transacting parties, trust and industrial atmosphere based on social embeddedness are important factors that enable these cooperative learning mechanisms (Lorenz 1992, Harrison 1991 pp. 477-478), and notions such as tacit knowledge and interactive learning, which are discussed in more detail in later sections of this study, play important roles. Another dimension of learning in the districts is the moving of employees between enterprises in search of a better match to their skills and better financial benefits. It is not seen as a loss for the system if an employee swaps jobs among companies, because skills and knowledge can still be utilized by the district at large and the move stimulates knowledge transfers between firms (Becattini 1990b p. 42).

However, it has been remarked that industrial districts produce and share knowledge through “learning-by-doing” and “learning-by-using” and are consequently better able to deal with incremental innovations rather than raptures (Asheim 2000 p. 421). For a given technology, a district can be very capable in exhausting its possibilities, but once an alternative appears, it may prove difficult for the district members to drop old ways and embrace new practices. On a different note, Storper distinguishes between agglomerations of high-technology industries, which he names “technology districts,” and others, but these locations are, according to him, still particular forms of Marshallian industrial districts and share characteristics with them (intricate social division of labour, behavioural-institutional sources of learning, adaptation of industrial best-practices and so on) (Storper 1992 pp. 89-91, Storper 1993 p. 450).

In certain cases, mechanisms supported by public funds give an industrial district its dynamism and competitiveness. Brusco defines this as “Mark II” model of industrial districts, where certain types of government intervention, which he calls “real services”, are offered (Brusco 1990 p. 13, Brusco 1992). It was an unconventional act to speak of “government intervention” in the immediate post-Teacher-Reagan world, when impartiality of government to goings-on in the economy was preached. Real services could be the provision of market information (e.g. on “standards enforced in different countries”), quality-inducing services (e.g. testing of input or product quality), supply of specialized technical tools (e.g. software tools customized for the district’s firms’ needs) or training schemes that make room for skills-upgrading and better matching in the employment market, all of which can be crucial for districts to maintain competitiveness and avoid decline. These services were to be provided by “offering the firm what they need in kind, instead of offering them money to buy what they need” (Brusco 1990 p. 17). One reason such services are not developed through market mechanisms is cost: it takes significant resources to build that type of knowledge pools and the return on investment is long. Secondly, demand issue is not very straightforward; there is often a lack of awareness among smaller firms regarding the benefits of such mechanisms and services. This double-ended task – both producing the service and generating the demand for it – cannot be executed by market mechanisms. Yet it is very essential as it activates a transformation rather than forcing it through.

Criticism on Marshallian Industrial Districts

The closer scrutiny of the industrial district concept that came with this interest exposed some theoretical shortcomings and disparities between industrial reality and district theory. The literature on industrial districts build theories on dualities: Fordist vs. post-Fordist, which means mass production vs. batch production based on craft skills, which means centrally managed big enterprise vs. flexible specialized spatial agglomeration of small firms, which means economies of scale vs. economies of scope, to name a few (Amin 1994 p. 15). Yet, as Amin and Robins discuss in detail in their important contribution to the discourse on industrial districts, historical and current industrial reality do not correspond fully to this picture of overlapping dualities (Amin/Robins 1990). The staged historic and economic development that was claimed to have taken place naturally disregards the fact that structural change does not consist of clear-cut epochs and very often it is impossible to draw a line between "stages." Amin and Robins also point out the fact that neither regional networks nor batch and craft production was non-existent before industrial districts, offering Detroit and Turin as examples (ibid. 203). For example, the belief that custom made products are beginning to replace mass-made items still does not match with reality. It is true that customers enjoy a much wider extent of customization, especially as far as technology-rich products like computers and automobiles are concerned, but since the early 90's, aside from exceptions such as film-making in Hollywood, production has been dominated by large flexibly mass-producing factories or organizations (Mair 1994 p. 19, Markusen 2003 p. 706).

Markusen (1996, p. 296) suggested alternative forms to the Marshallian industrial district: 1) a hub-and-spoke industrial district, where regional structure revolves around one or more dominant, externally oriented firms; 2) a satellite industrial platform, comprised chiefly of branch plants of absent multinational corporations (embedded in external organization links) and 3) the state-anchored district, with one or more public-sector institutions. In this picture, the Marshallian district is a distinct fourth type of structure. In many locations, larger enterprises are nodes of regional industrial systems, as in Baden-Württemberg or even Silicon Valley.

Another curious point of district theory is the way culture and cultural values are handled. In industrial districts literature, it appears as if the culture and social perceptions of a location can only work for the good of locality and cannot be corrupted. Then again, although the shared language, values and norms ease communication among individuals, there is neither a guarantee that interaction will occur, not that the outcomes of the interaction have to be positive in all cases (Alberti 2006 p. 484 and 486). Especially under conditions of competition, local culture can be "contaminated" by hostile feelings among actors, which can cause "proximity without intimacy or interaction" and the members of the district ultimately choose supra-local partnerships over local ones (Hendry et al. 2000 p. 140, Pfoertsch/Tözün 2008 [forthcoming]).

2.2.2. Porter's cluster concept

In the rich body of literature on spatiality of economy, arguably no one has stirred as much interest in regional agglomerations outside the inner circle of the field as Michael Porter. Besides his impact on economic geography literature, the model he devised in his book "Competitive Advantage of Nations", which was first printed in 1990, was adopted by policy makers and practitioners from all levels and corners. His model did attract criticism as well, which will be addressed later in this section.

The term cluster is actually mentioned elsewhere in literature well before it turned into a buzz-word after Porter. Hoover writes about the clustering of an activity, citing several grounds for its existence. Firstly, he claims, it could be linked to "output-oriented activity whose markets are concentrated at one or a few locations and correspondingly for units of an activity-oriented input whose source locations are few" (Hoover 1971 p. 75). Another competition-oriented reason is the "mutual attraction" among the competitors in a field of activity, for example retail units for similar products (ibid. p. 76). Elsewhere in the same publication, Hoover turns to the clustering of manufacturing activities, comments on economies of size, and suggests three main levels: 1) individual location unit (plant, store or alike), 2) the individual firm itself and 3) "economies with the size of the agglomeration of that activity at a *location*" (ibid. p. 79, emphasis in original). Hoover likens the latter "cluster economies" to Marshall's localisation economies notion. However, he does not go as far as drawing a unitary concept as Porter did.

In his seminal book "Competitive Advantage of Regions", Porter begins his argumentation by discussing national competitiveness, on which he is an internally renowned figure. He dismisses the notion that prosperity per se is a measure of a nation's competitiveness, and declares that national productivity provides the required measure of it, owing to its direct effect on national per capita income. Porter also declares that sustained productivity growth is only possible through, therefore is a sign of, upgrading of the economy. He continues to point out the fact that no nation can be capable of being a net exporter of – and therefore competitive in – everything, hence a nation is under the obligation to upgrade itself in its existing industries and step into sophisticated industries and segments. According to Porter, this situation, i.e. the existence of sector-specific disparities, is the basis of international trade and a nation's exports are composed of goods it produces with high productivity and its imports otherwise. The target for a nation is to increase the productivity of its economy and the sophistication of its exports.

For the question of how productivity develops, Porter chooses to focus on specific industries and segments, rather than drawing all-encompassing arguments (Porter 1998a pp. 1-30). In doing so, he also signals the groups he wishes to address: "…an examination at this level must by necessity focus on very broad and general determinants that are not sufficiently complete and operational to guide *company strategy or public policy*" (Porter 1998a p. 9, emphasis added).

Porter repeatedly draws on the term "competitive advantage", which he championed previously in his writings on business. He describes competitive advantage as follows (1985 p. 3): "Competitive advantage grows out of value a firm is able to create for its buyers that exceed the firm's cost of creating it. Value is what buyers are willing to pay, and superior value stems from offering lower price than competitors for equivalent benefits or providing unique benefits that more than offset a higher price. There are two basic types of competitive advantage: cost leadership and differentiation." The competition takes place among firms, not locales or countries, yet according to Porter, a nation can exert its influence on a competitive landscape through industries. The link is provided through the interplay between productivity growth and competitive advantage. Sustainable competitive advantages can only be built by continuously delivering higher-quality products and services or by producing ever more efficiently, which Porter claims would co-stimulate productivity growth. Porter does not subscribe to equilibrium seeking systems – at least not in his cluster theory –, but instead builds on disequilibrium a la Schumpeter and stresses the dynamic and evolving character of competition (Porter 1998a p. 20).

Porter suggests a link between spatiality and competitive advantage in his "home base" notion, which he defines as "the nation in which the essential competitive advantages of the enterprise are created and sustained" (Knox and Agnew 1998 p. 103, Porter 1998a p. 19). As will be explained later in more detail, Porter attributes sustaining competitive advantages largely to innovativeness in its broadest meaning. A home base covers ownership, advanced enterprise skills and most sophisticated processes so accommodates innovation stimulating resources, structures and relations. In other words, home base is where the enterprise is more likely to be its most innovative self. Home base activities include primarily creation and renewal of products, strategic processes and services (Porter 2000 p. 267). This is even independent of the nationality of shareholder structures, so long as the operation in a locality retains effective strategic, creative and technological control. The location of a home base, after all, would be decided by total system costs and innovation potentials.

Clustering of industries

Porter deals with the geographical agglomeration of industries in his cluster notion. According to Porter, a cluster is “[a] geographic concentration of interconnected companies, specialized suppliers and service providers, firms in related industries and associated institutions (e.g. universities, standards agencies, trade associations) in particular fields that compete but also cooperate” or a “geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities” (Porter 1998b p. 78, Porter 2000 pp. 253-254). Clustering on a location offers an alternative form of industrial organization as compared to markets and hierarchies by shaping the trade-offs between these two (Porter 2000 p. 264). These firms, which are bound by exchange relations, include both upstream and downstream partners, services firms, specialized suppliers, financial institutions and more, and they are complemented by numerous institutions that supply education, training, research, standards setting agencies, relevant government agencies and trade associations. According to Porter, the clustering of industries develops from the determinants of national advantage and it reflects the systematic character of the diamond (Fig. 5) (Porter 1998a p. 149). As such, the components of the diamond mutually reinforce each other, creating favourable conditions for others. For instance, an extraordinary local demand alone cannot create the upgrading of an industry unless a functioning culture of rivalry is in place.

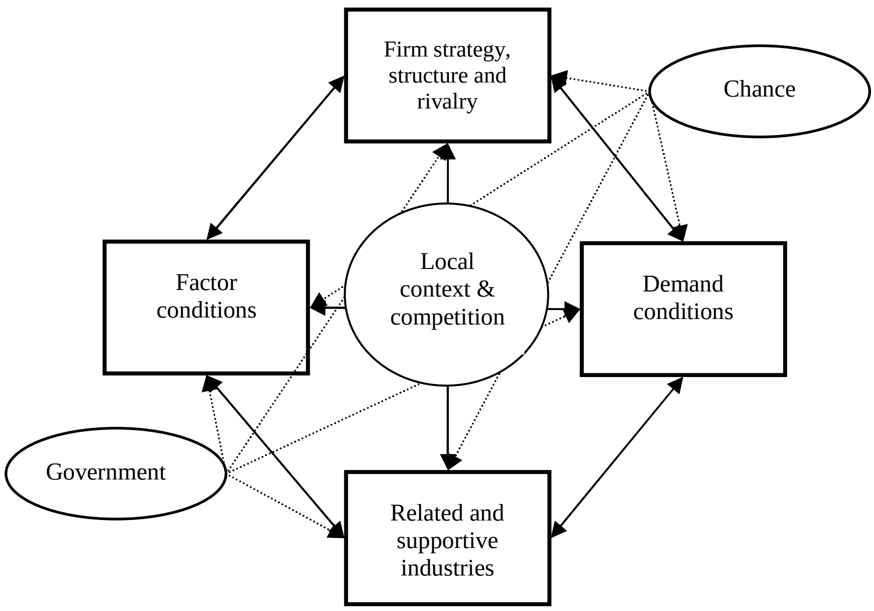

Fig. 5: The determinants of national advantage, aka “Porter’s diamond”

Source: Porter 1998a p. 127

The advantages of clusters are derived primarily through competition and innovation, which stimulate them in various ways. A cluster's influence on competition and competitive advantage is shaped in three ways: by increasing the static productivity of resident firms and industries, by increasing their capacity for innovation and by stimulating the formation of new businesses, which expand the cluster and boost innovativeness (Porter 2000 p. 259, Porter 1998b p. 80). The first is along the lines of Marshallian externalities; being in a cluster allows firms to access inputs and human resources unavailable or more costly elsewhere. For innovativeness, clusters offer a wide array of opportunities. Porter writes: "Proximity, supply, and technological linkages and the existence of repeated, personal relationships and community ties fostering trust, facilitate the information and knowledge flow within clusters", and "local suppliers and partners can and do get closely involved in the innovation process, thus ensuring that the inputs they supply better meet firm's requirements" (Porter 2000 p. 260 and 262). Clearly, these arguments mirror that which various authors wrote on learning regions, innovation systems, untraded interdependencies and innovative milieus (Perrin 1991, Storper 1997 pp. 18-22, Malmberg 1997). The complementarity of cluster members' products, locally available services like training, and even knowledge as a "quasi-public" good are also mentioned by Porter (Porter 1998b p. 83). The last point inevitably brings Marshall's famous quote to mind: "The mysteries of the trade become no mysteries; but are as it were in the air…" (Marshall 1925 p. 271). In clusters, Porter claims, information regarding the market are more readily available than elsewhere, i.e. individuals can identify gaps in products and services, and thanks to the resources available in the cluster, are advantageously positioned to fill them, due to lower barriers to entry (Porter 2000 p. 263). The firms outside clusters would also be allured to a cluster location, in order to tap in on the pool of advantages available there.

Observing the distribution of industrial activity and leaning in the preceding arguments, Porter claims that the systematic nature of the "diamond" initiates the regional agglomeration of industries. Industrial evolution triggers new industrial activity, which tends to cluster at different locations. Porter explains the emergence of clusters chiefly with respect to markets and firms' reaction thereof. Not only the size and characteristics of demand, but also expectations of changes in demand can also initiate investments that start-up a cluster. The nation- or location-specific conditions and the elements and dynamics pictured in the diamond play their part in shaping the structure and direction of a regional industrial agglomeration. A nation's different industries cluster across its geography and are connected through vertical and horizontal links, assisting each other development.

Once a cluster is up and running, its survival and further development are largely dependent on the industry's creation and utilization of knowledge and technology. This applies to so-called mature industries as much as it applies to new ones. According to Porter, the increasing mobility and decreasing cost of factors through the globalization of markets and technological developments weaken the pure urbanisation or localisation externalities, and the systemic nature and interdependencies of the cluster lead to real advantages today.

Supra-cluster relations appear chiefly as a complementary element. Staying true to his "competition first" mantra, Porter puts it before all else, therefore if a factor that could bring competitive advantage appears, a firm should not refrain from obtaining it. Demanding foreign markets, cheaper materials and overseas research capacities should be utilized, yet a firm should protect its dynamism and capacity at the home base, for it is the core of its competitive position (Porter 1998a pp. 606-607). Clearly, this firm level behaviour also addresses how industries are expected to function.

Porter's cluster theory, policy-making and criticism

Following the political changes that redrew borders and made them permeable for capital and trade, for example with the establishment of free trade areas such as the European Union, NAFTA and ASEAN, the interventionary Keynesian economic policies became rather ineffective (Cooke 1999 pp. 54-56). After ensuing liberalization and deregulation drive, the nation state was nearly stripped off its old tools like tax relieves and large-scale grants and it seemed to retreat from the economy. At this point, regional level governance appeared to be an appropriate answer to the challenges on hand under prevailing fiscal constraints. About the same time, in the face of increasing price pressures on established western industries, the word innovation grew increasingly popular in western governance realms. Organizations like OECD and World Bank pushed regional level innovation support agendas into discussion, assigning Porter's cluster concept a prominent role (OECD 1999, Martin/Sunley 2000 p. 6).

The European Union, too, made avail of regional level support to close economical and structural gaps across Europe and to accelerate the sluggish homogenization of governance practices (Rossi 2005 p. 17). Cluster has been a key term for the support activities of the European Commission's Enterprise and Industry Directorate General (DG Enterprise), which is the operational unit that deals with the business environment[7]. National and sub-national governance levels in Europe did embrace the cluster theory of Michael Porter as a guideline. Indeed, it is not an exaggeration to claim that at the moment Porter's cluster concept (or a

[7] An example to this end is the document: „*Regional Clusters in Europe*"(Isaksen & Hauge 2002).

derivative version of it) is the de facto standard in regional public policies in Europe. This most extraordinary success becomes even more surprising if one considers the comparably little impact alternative concepts like “industrial districts”, “new industrial spaces”, “innovative milieus” and “learning regions” managed to create on the “policy-making market” (Florida 1995, Scott 1988, Perrin 1991, Asheim 1996, Harrison 1991).

Looking at the criticism on Porter’s cluster concept, it is impossible to miss the fact that most of what economic geographers consider as shortcomings are actually the grounds for the cluster concept’s attractiveness in the perception of policy makers. To begin with, the language Porter has chosen is lucid, commonsensical and uncluttered with academic discourse, which makes it more approachable and apprehensible to a wider audience (Martin/Sunley 2003 p. 9). In his alluring business-friendly and self-assured tone Porter cites, rephrases and mixes ideas and concepts that have been minutely discussed elsewhere in economic geography literature. Beside the built-in practicality of language, the ease of visualization provided by the diamond makes Porter’s theory highly accessible and practical for business and policy-making purposes.

Porter’s celebrated position as an international figure in business literature is also an important factor, which has prompted many to read about spatial agglomerations in the first place. Secondly, the leading elements of Porter’s cluster concept are competition and competitiveness, which coincide with the discourse in business literature and press. The last point of criticism, arguably the most disturbing for the sensibilities of economic geographers, is the generic character of Porter’s writing (Martin/Sunley 2003 p. 9, Newlands 2003 522). No geographical scale is defined – a cluster can cover anything from a city to neighbouring regions from two different countries to smaller nations (Porter 2000 p. 254). As long as business processes bind firms together, one can talk of a cluster, and indeed, the elastic spatiality of Porter’s cluster makes it a distant, business-focused relative to functional regions (OECD 2002 p. 11). The “all-embracing” character Porter’s cluster concept played a role in its popularity as a way of seeing and comprehending regional economic agglomerations. What is defined by Martin and Sunley (2003, p. 26) as “confusing cluster framework” can be seen in policy-making practice as a uniting concept that everyone and anyone can make use of at will. Not surprisingly, its vague character has led to confusion about its definition, especially in the minds of policy-makers, to the extent that clusters, networks, cluster management and other constructs came to be tagged under the “cluster” banner. The multiplicity of cluster’s definition is also reflected in academic literature, (ibid. p. 12). Porter himself describes clusters as “a geographically proximate group of interconnected companies, suppliers, service providers and associated institutions in a particular field, linked by externalities of various types", which this study adapts as a reference point (Porter 2003 p. 562).

2.2.3. Localized learning and learning regions

As mentioned briefly in preceding chapters, innovation and interactive learning have been put forward as critical mechanisms that trigger the formation and survival of spatial agglomerations (Cooke/Morgan 1990 p. 73, Asheim 1996, Malmberg/Maskell 2002 p. 440). In this section the sources of localized learning is presented along three dimensions: vertical, horizontal and social (Malmberg/Maskell 2006 pp. 5-8).

The vertical dimension of spatial proximity and learning

The vertical dimension deals with the knowledge-production effect of supply relations, which have been discussed in the preceding pages. These relations are also important components of industrial districts literature and Porter's theory of industrial clusters. The low costs of interaction and coordination due to geographical proximity not only animate these relations, but also stimulate increased specialisation, which in turn provides cognitive differences that enable learning relations (Boschma 2005 p. 64). However, as Malmberg and Maskell point out, there is little evidence that supply-relations are exclusively localized and if one considers decreasing national value-added numbers this indeed might not be the case (Malmberg/Maskell 2006 p. 6, Sinn 2006 p. 1161). Still, locations such as Silicon Valley, which – despite their links to overseas manufacturing locations – survive on the vitality of local supply relations, local exchanges matter for knowledge-intensive sections of supply relations (Saxenian/Hsu 2001). Sternberg's empirical study of German regions also supports the role of supply relationships for knowledge-production (Sternberg 1999 p. 534).

The horizontal dimension of spatial proximity and learning

The horizontal dimension relates to the relations between firms of the same or related industries that share a locality. Rivalry and competition are more common along the horizontal than vertical dimension, which complicates efforts for direct collaboration or interaction among enterprises (Dodgson 1996 p. 285). Thereby, horizontal learning often works through indirect ways, independent of intra-cluster interaction (Maskell 2001 p. 930). Spatial proximity accommodates and animates a continuous monitoring and comparison among companies[8] (Bathelt et al. 2004 p. 36). The observability aspect requires almost no effort or no direct interaction as firms from similar fields, given a cognitive proximity basis, will pick-up others' successful ventures and activities (Malmberg/Maskell 2006 p. 6, Boschma 2005 p. 64 and 69).

As the shared location nullifies any static and purely locational advantages, such as factor costs or access to a local market, there are competitive incentives to identify successful activities and to emulate these (Porter 1998a p. 119). This enables and stimulates firms to continuously combine and re-combine their resources to produce new knowledge giving them an edge over their rivals and letting them proceed down different paths (Maskell 2001 p. 928-930, Bathelt et al. 2004 p. 37). The resultant dynamics lead to a vibrant cluster where learning, specialisation and local rivalry motivate and inspire each other.

On a different note, it would also be helpful to remember the notion of collective technological assets of a location. Dosi claims that there may be untraded interdependencies[9] between sectors, technologies and firms, which take the form of "technological complementarities, 'synergies' and flow of stimuli and constraints which do not entirely correspond to commodity flows" (Dosi 1988 p. 226). Once a firm manages to embed itself in a location, it can build the necessary social and cognitive proximities to tap into the technological complementarities. At the same time, an enterprise can position itself knowledge-wise with respect to its peers and customers in order to find a dynamic balance between cognitive proximity and distance to others[10].

The social dimension of spatial proximity based learning

The third so-called social dimension of localized learning is an outcome of working and living in a local setting and consists of interactive learning effects through *unintended* encounters and knowledge spillovers (Audretsch/Feldman 1996). The learning region concept suggests

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[8] It is all but unavoidable to remember what Marshall wrote the following on industrial districts: "The mysteries of the trade become no mysteries; but are as it were in the air,…Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further ideas." (Marshall 1925 p. 271).

[9] Although this term was made "famous" during the 1990's by Storper who defined it as "conventions, informal rules, and habits that coordinate economic actors under conditions of uncertainty" (Storper 1997 p. 5), it was actually Dosi (and Lundvall) who first suggested it in the late 1980's.

[10] Schamp et al.'s (2004 p. 620-622) account of relations knowledge-based networks in the metropolitan region of Frankfurt/Rheine-Main provides findings to this end.

that knowledge is created interactively and collaboratively; that shared values and identity assist (and indeed stimulate) knowledge creation and that their (re-)production is enabled by spatial proximity. An important concept regarding the social dimension of localized learning is the “local buzz” concept, which provides a metaphor to define the “information and communication ecology” that stimulates knowledge exchanges and knowledge production (Storper/Venables 2004 p. 61, Malmberg/Maskell 2006 p. 7). For Storper and Venables, buzz is a superadditive form of information circulation that results from the externalities of organized F2F processes and the enablers of the local buzz as a mechanism are “similar language, technological attitudes and interpretive schemes”, which are claimed to be stimulated by spatial proximity. These localized F2F contacts facilitate evolution, mutual identification and collaboration among perceptive actors in a continuously updated manner[11].

Important as localized knowledge production processes are, the variety of market peculiarities in respective industries and divergent innovation strategies of enterprises underline the need to operate in a broader geographical context (Hotz-Hart 2000 pp. 440-442). Thereby one can interpret local/regional, national and global networks and systems of innovation as layers of a “world order” (ibid. p. 445) and perhaps one should do so, considering the increasingly dynamic flow of goods, people and services through borders. Amid this global criss-cross of materials and information, localized knowledge-production finds its place due to the reasons explained above. However, the competitiveness and survival of regions depend increasingly on their ability to connect their local knowledge-production processes and networks with global knowledge flows (Bathelt et al. 2004 pp. 45-47, Wolfe/Gertler 2004 pp. 1077-1079). The well-discussed “local buzz-global pipelines” model of regional agglomeration and knowledge-production suggests that localities with high vibrant local buzz would attract contacts with other high-buzz locations, creating a form of interactive learning. Although this happens predominantly at the firm level, the information acquired through pipelines would spill over to others through the local buzz (Fig. 6).

[11] The field study carried out by Sternberg & Tamásy in Munich region provides empirical evidence regarding the role of informal localized contacts in knowledge production related relations (1999 p. 374).

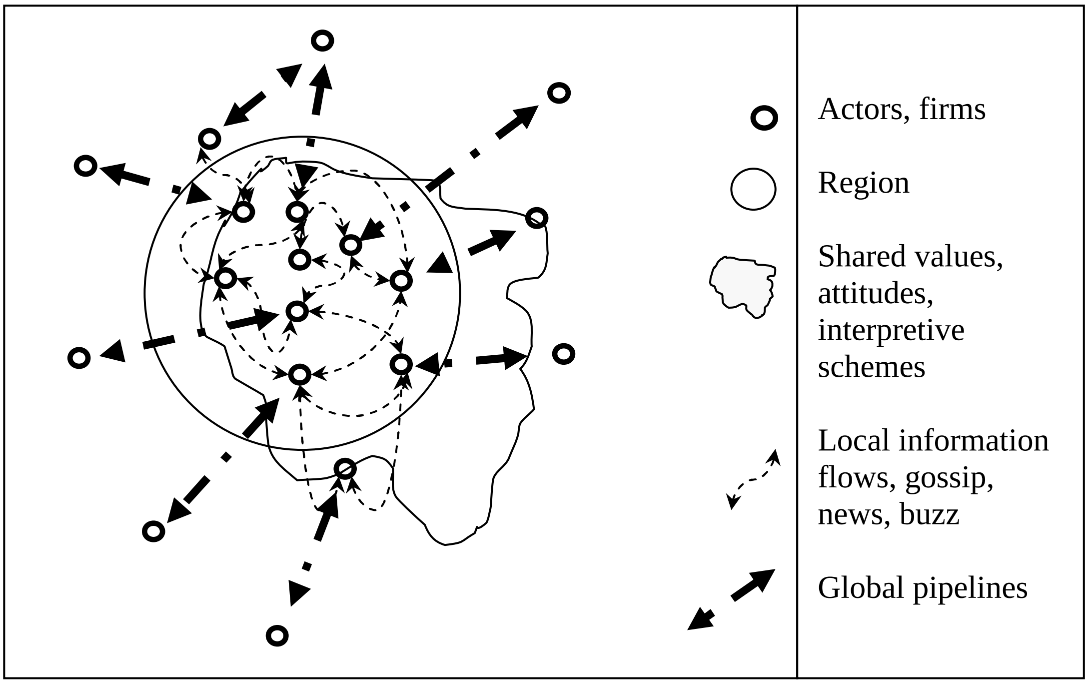

Fig. 6: The structure of local buzz-global pipelines

Source: Bathelt et al. 2004 p. 46

This mutually reinforcing process ensures dynamic enterprises and attracts new actors and investment to a region, thereby ensuring its vitality. If the firms on a location fail to build external contacts and local interactive communication ecology is not build-up, then this can lead to a weakening cluster (Bathelt 2005 p. 120). The importance of trans-local connections is clearly undeniable, especially when global communities of practice and increasing mobility of individuals are considered (Amin/Cohendet 2005 p. 482, Saxenian/Hsu 2001 pp. 915-917, Gertler 2003 p. 86). Therefore, it is necessary to see localized learning in a supra-regional context, and interpret the significance of localized learning consequently.

2.2.4. Lead firms and regions: some customers are bigger than others

Although a central point of interest in international business writing, large enterprises have attracted less attention than smaller firms in economic geography literature. Extensive debates on post-Fordism reported the end of large, integrated firms, and the more talked about locations such as Emilia Romagna and Baden-Württemberg were investigated in the context of localized small firm networks (Scott and Storper 1992 pp. 6-8, Capecchi 1990, Becattini 1990a pp. 163-168, Cooke/Morgan 1990). However, interest in large enterprises was not completely absent, and especially debates on globalization dealt with them and their locational behaviour (Dicken et al. 1994, Tödling 1994, Porter/Sölvell 1998 pp. 449-452). Porter, too, chooses most of his examples in “Competitive Advantage of Regions” from the realm of large enterprises (Porter 1998a p. 98, 119 and 210). Indeed, investigations on regional agglomerations, where large enterprises and swarms of smaller firms co-exist and engage in exchange relations, revealed prolific relations and mutual interdependencies (Storper 1993 pp. 442-445, Sternberg 1999 pp. 373-375). Besides, even in much-discussed small firm networks around the automotive and electronics industries in Baden-Württemberg, large firms control large localized supply chains and dominate local relations (Schmitz 1992 pp. 98-100). Therefore, it is counter-productive to ignore larger enterprises and the prominent roles they often play with regard to regional agglomerations.

Enterprises operate through multiple interrelationships through which exchanges for products and services take place between pairs or networks of firms. These exchanges often take the form of exchange relations in supply-chains or value systems. According to the terminology popularized by Porter, the internal activities of an enterprise constitute a value chain, which extends itself by linking with those of other enterprises to form value systems (Fig. 7 and 8) (Porter 1985 pp. 33-61). Similar constructs are named as production chains ("a transactionally linked sequence of functions in which each stage adds value to the process of production of goods or services") (Dicken 1998 p. 7) or supply chains ("the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer") (Christopher 1992 in Mentzer et al. 2001 p. 3). Often firms that control either the completion or the distribution phases of the chain have an overbearing influence on the governance and functioning of supply relationships. Such firms that play a lead role and their regional influences are the focus of the remainder of this section.

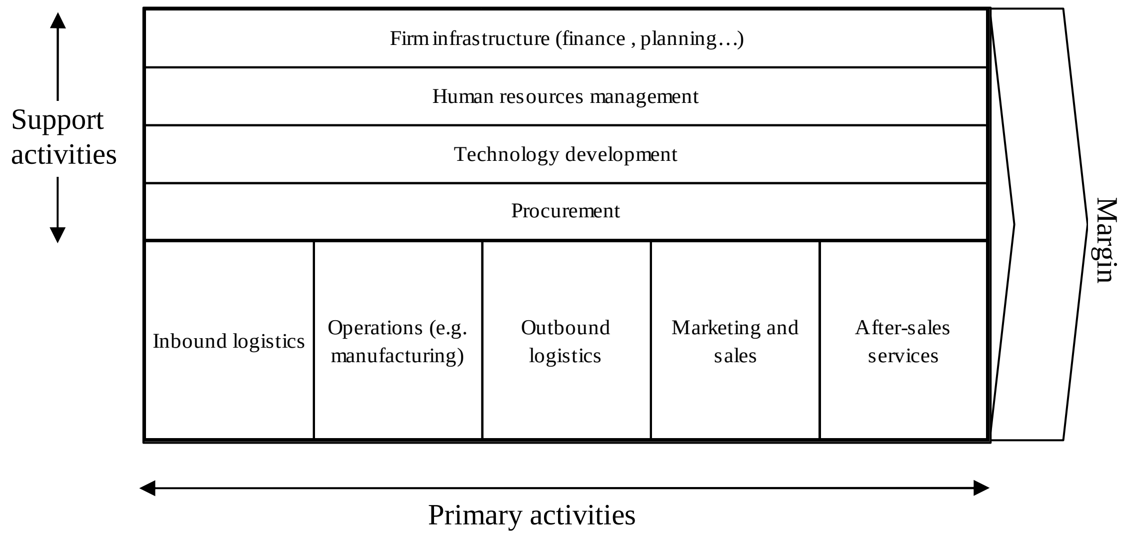

Fig. 7: Value chain of an enterprise

Source: Porter 1985 p. 37

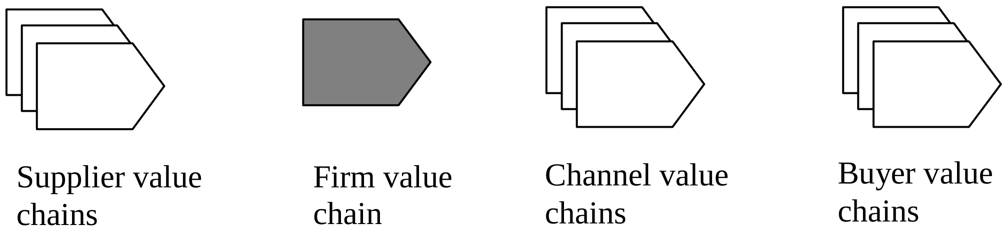

Fig. 8: The value system

Source: Porter 1985 p. 35

These supply relations comprise not only the production of physical parts, but also services activities in areas including - but not limited to – design, development, consulting and logistics (Dicken 1998 pp. 387-388). These exchange relations increasingly structure themselves into networked relations where knowledge-intensive tasks are also externalized by larger firms (Tödling 1994, Schamp et al. 2003 pp. 615-619). Although transaction costs have been decreasing due to technological innovations and infrastructural developments, supply relations have relational contents that are aversely sensitive to geographical distance and there are various economies of proximity that motivate large and small firms to agglomerate around each other (Storper 1997 pp. 179-180).

In such geographical agglomerations, large enterprises can play different roles. Starting with the aim of creating “an ideal industrial community”, Toyota Corporation chose to settle its main operations in 1937 in Koromo, an old industrial area suffering from the desolating silk industry. Attracted by cheap land, supply of work force and supportive local authorities, Toyota constructed its manufacturing operations in this remote area, which came to be renamed Toyota City in 1959. Toyota favoured close and flexible working relationships with suppliers from the beginning and partly for this reason it emphasized the geographic concentration of its activities and its suppliers. Thereby, Toyota built an industrial district around itself from scratch, which included layers of suppliers and functions, and the relationships that provided the template for Toyota's cooperative was of working with its suppliers (Hayter 1997 pp. 353-355).

In the famed Silicon Valley, large enterprises provided the demand that created the necessary complementary effects and upstream growth impulse that co-created the Silicon Valley of today (Bresnahan et al. p. 849). Silicon Valley's beginnings, or "genesis" as Saxenian tags it (1994 p. 11), had universities and university-based research at its core. Not only in terms of the development of technology, but also the personal and institutional support and encouragement for individuals took place on university soil, e.g. Stanford (Saxenian 1994 pp. 20-24, Scott 1988 pp. 89-90). Indeed, Stanford University and Frederick Terman helped Hewlett-Packard to come into being and to grow (Saxenian 1995 pp. 3-5). Yet, there had been other factors as well. To begin with – during the Second World War – Santa Clara Valley and its surroundings, where Silicon Valley is located today, proliferated with war spending. After 1945, larger enterprises like Xerox, IBM and ITT started to move in with their R&D, administration and manufacturing operations, and became the drivers of regional growth. They expanded the regional technical infrastructure and skill base by attracting talent; supported the growth of local supplier bases and were sources of start-ups in different fields (Saxenian 1994 p. 24). These supplier bases played an important role in providing start-up firms with complementary capabilities that enabled and accelerated their development and manufacturing (ibid. p. 26). During this time, the military installations in and around the area also played important roles as lucrative markets and magnets of talent (Scott 1988 p. 90).

In both these examples, the lead firms largely occupy the demand side, while smaller enterprises supply inputs to them. The opposite can be seen in the East-Württemberg Region of Germany, where Carl Zeiss provides the inputs and knowledge that smaller enterprises utilize to build their businesses on (Pfoertsch/Tözün 2008 [expected]). In the case of Munich, Siemens is not only a provider of inputs to smaller firms in the Munich area, but also one of their significant customers for products and services (Sternberg 1999 p. 370). Hence, the vertical relations between large and smaller enterprises of a region can go both ways and while doing so they can potentially function as channels of creativity and innovativeness when a functional networking exists.

In order to discern the spatiality of a large establishment, it is also necessary to identify which portions of the value chain are carried out on that location. When a significant portion of knowledge lies within the supplying networks, in which the knowledge contained is compounded through exchange relationships, these networks extend the internal economies of scale and scope of large and small enterprises, and create localized externalization benefits (Dicken 1998 pp. 172-174). Thereby, exchange relations do not depend solely on price and a large firm turns into a lead enterprise as it embeds itself further in these localized networks (Granovetter 1985).

At this point, the role of local demand in Porter's cluster concept can provide an additional explanation for the role of lead firms in regional agglomerations. Porter claims that a large and growing home market would offer firms and industries early signals about customers' preferences, push them to innovate and provide them with economies of scale that would assist them on their path into foreign markets (Porter 1998a p. 86, 89 and 93). In his reasoning, Porter avoids leaning solely on scale economies: "the absolute size of segments within a nation plays a complicated role in competitive national advantage, because firms compete globally and can achieve a large scale even if their home market is small", and the most influence of home demand is through "the mix and character of home buyer needs" (ibid. pp. 86-87). Although he states that a burgeoning local demand situation would increase new firm entries, Porter largely sidetracks the role of local demand on new firm creation and claims, "presence of sophisticated and demanding buyers is as, or more, important to sustaining advantage as to creating it" (ibid. p. 89 and 114).

Elsewhere in literature, existence of local demand is listed among factors that trigger regional agglomerations. To begin with, existence of demand is a factor in the location decisions of enterprises and creation of new enterprises (Krugman 1991 p. 15, Keeble/Weever 1986 p. 21). New firms tend to have a limited geographical reach at the early phases of their development and local demand is a factor in their survival rates (Keeble/Weever 1986 p. 22). This argument relates to the life cycle model for small firms, which implies that a small firm expands its geographical reach as it grows and augments additional knowledge, capacities and contacts (Hayter 1997 pp. 237-238). The flow of new enterprises is also supported by spin-offs from local customers, as individuals seek to pursue their own ideas (Storper 1997 pp. 157-158). These spin-offs increase the vertical and horizontal divisions of labour in the region and together with “human capital” specific to the location and with their existing contacts; they mix in well with the regional industrial fabric. Indeed, smaller firms have a higher propensity to source locally and add to the vitality of localities (Hayter 1997 pp. 240-241).

An important notion for Porter is the role of demanding home buyers, who are literally main protagonists in the story. To begin with, their challenging and sophisticated expectations and the size of the home market shape “the attention and priorities of a nation’s firms” (Porter 1998a p. 87). Sophistication of demand refers to the content-depth, variety and customization of products and services requested by customers, challenging delivery cycles, quality standards and pricing, demands on the pace of improvements and active involvement in customers’ processes. Furthermore, Porter drives his point for learning and innovation home in very common-sense language in which the role of geography and proximities are blended together: “proximity, both physical and cultural, to these buyers helps a nation’s firms perceive new needs” (ibid. p. 89) and furthermore „open communication” and “intuitive grasp of buyer’s circumstances” push innovativeness higher (ibid. p. 86). Bresnahan et al. (2001 pp. 839-840) also state that the faster transfer of innovation to commercialization due to proximity to customers increases the rate of capture of rents and returns on innovation, hence boosting incentives thereof further.

Porter assigns a cognitive deterministic role to local buyers over local firms, as they pre-define the direction and content of the supply. Here, in addition to geographical and social proximity, cognitive proximity is also stressed, albeit only between the lines. The motivation to act on these insights on customer needs is stimulated by proximities and home market characteristics. When located spatially close to a large market, whose needs are easier to comprehend than that of export markets, firms are compelled to respond to these needs. Therefore, according to Porter, geographical proximity not only accommodates the mechanisms of communication and coordination, but also solves incentive problems in conditions of uncertainty. Should the home market predate the global demand; local firms earn a valuable head-start against their competitors who do not utilize such resources.

In the absence of customers with specific requests, enterprises would try to remain flexible to reduce risks. Yet, such a strategy also exposes a higher number of competitors and potentially decreases chances of survival. However, identifying a sustained demand of distinctive character gives firms incentives to invest in specific skills, capacities and processes that will lead to branch-labour. Therefore, on the one hand, a firm takes on risks in terms of potentially irreversible investments, while on the other hand, decreasing the number of competitors and starting to build a competitive advantage over others. Demand in itself is not sufficient for labour without other necessary factors such as human resources or related infrastructures, but, ceteris paribus, distinctive demand conditions can trigger labour among supplying firms. The firms' response to demand conditions is co-determined by rivalry conditions, and a large home market with little competition can push firms into complacency. As mentioned in more detail later in this section, competition is the primary mechanism in the horizontal dimension of Porter's model. Vertically, in addition to customers' importance, national suppliers play decisive roles, as they allow firms to respond to challenges: after all, firms in one industry constitute the home market for another (Porter 1998a p. 100).

2.2.5. Spatiality of knowledge-intensive business and producer services

Following an early account by Clark, a three-layered form of classifying sectors was adopted in Anglo-Saxon economics discourse (Wolfe 1955 pp. 402-404); namely, the "primary sector that extracts raw materials (and sometimes goods) from the environment via activities such as mining and agriculture and the secondary sector transforms raw materials into goods, buildings, infrastructure, and physical utilities like water and electricity supplies" (Miles/Boden 2000 p. 3).

The definition of the tertiary (or services) sector has been more challenging to formulate. At first, services were defined as a residual of all that did not belong to the primary or secondary groups. Then the emphasis shifted to common characteristics of tertiary sectors that differentiated them from other types of activity e.g. intangibility, non-transferability or perishability, and their labour intensivity, when compared with other sectors. However, the increasing use of technology in services increased the discrepancies between services, which made the last definition unclear (Weller 2004 p. 159). More recent definitions, despite being a little more abstract, appear to provide enough depth to cover the tertiary sector in general: "the tertiary sectors transform the state of material goods, people themselves, or symbolic material (information)" (Miles 1996 p. 243). As Miles himself mentions, this definition also relates to an older account by Hill: "a service may be defined as a change in the condition of a person or a good belonging to some economic unit, which is brought as the result of the activity of some other economic unit, with the prior agreement of the former person or economic unit" (Hill in Illeris 1996 pp. 12-13). Following these accounts, one can be tempted to call services "intangible goods" or "symbolic products."

The classification of services is a difficult endeavour in itself as well. They can be classified according to the markets they serve, meaning consumer, producer (intermediate) and public services, or based on their subjects (or ends): physical services (e.g. maintenance, transport and exchange of facilities, goods or people), human-centred services (e.g. health, education, welfare) and information services (e.g. media, advertising and engineering services) (Miles 1996 p. 247, 1993 pp. 656-658). This last group includes the so-called knowledge intensive business services (KIBS), which is of interest to the present study. KIBS is an indicator of the knowledge intensive and sophisticated side of the burgeoning services economy, especially in developed countries (Dicken 1998 p. 387, Hauknes 1999 p. 12). KIBS covers business / professional business / strategic business services, or knowledge based/knowledge intensive services (Nählinder 2002 p. 4), which similarly rely on specific professional knowledge and are very often customer specific in nature. Efforts to define KIBS statistically through R&D intensities lead to a list of occupations converging around ICT and business services, although there are other "potential" KIBS firms from logistics, market-research and training realms among others (Hauknes 1999 pp. 8-9).

KIBS firms develop the information or service products that generate knowledge products for other firms and sectors; i.e. they foster knowledge development outside their sphere. Besides, this knowledge production and delivery is dependent on firms' employees and procedures; therefore tacit knowledge and skills are highly crucial for KIBS enterprises. Secondly, KIBS firms very often base their service products and offerings on new or emerging technologies. However, their relation with technology is not uniform with some KIBS enterprises actively shaping technologies, while others solely utilize them. Finally, KIBS service products are very often customized in some form to comply with customers' needs, which accordingly requires continued interaction with clients (Nählinder 2002 pp. 5-6).

In the new world of innovation-mediated production, the boundaries between innovative and productive activities have grown very thin (Florida/Kenney 1993). In this environment, the awareness that intermediate services play an increasingly crucial role for the production of goods has manifested itself (Guerrieri &. Meliciani 2005 pp. 491-493). The group of services activity that is very closely linked to production, viz. producer or intermediate services, is also closely associated with KIBS. Producer services are "intermediate-demand functions that serve as inputs into the production of goods or of other services; [which] enhance the efficiency of operation and the value of output at various stages of the production process" and they can be located upstream and downstream of actual production (e.g. research and development, marketing) (Coffey/Bailly 1992 p. 858).

Some of these producer services are highly knowledge-intensive, for instance integrated just-in-time logistics, engineering, R&D and software services. In the regional context, knowledge-intensive producer services (KIPS) firms carry out different functions in terms of regional knowledge production and innovativeness. The first is the transfer of knowledge in the form of products, process know-how and industrial best-practices. Furthermore these firms integrate different bodies of knowledge and adapt these to the specific needs of customers. In some cases, this function could entail the conversion of scientific knowledge into applied and localized know-how through their services. Last but not least, KIPS do produce new knowledge as well (Strambach 1998 pp. 7-8, Hauknes 1999 p. 23).

The reasons for the growth of demand for KIBS and KIPS are similar: increasing knowledge intensity, complexity and fluidity of goods and (both internal and external) processes, challenges in reacting to the opportunities and constraints presented by the continuously changing social and economic environment and the organizational and cognitive flexibility required of the organizations to survive. These conditions demand the intervention of specialists, who not only offer advice but also carry out the necessary activities (e.g. analysis, information processing and so forth) (ibid. p. 859). There are a series of cost and non-cost factors that co-affect the externalisation of producer services to specialized enterprises like transaction costs, risk reduction and growing management complexity. It is an oft repeated argument that services need to be consumed where they are "produced" (or visa versa). A haircut, a clichéd example of the case, can be a good illustration of how things have changed: it is true to say that one cannot (yet) have a long-distance haircut, but the appointment for the haircut could be separated and carried out by an individual (or by a machine, for that matter) located elsewhere. As Castells and Hall remark, "all technical division of labour becomes, over time, a social division of labour" (1996 p. 5). However, in-house technical limitations and the infrequent and/or irregular demand for a particular service appear to be the crucial criteria for its externalisation (Coe 2000 p. 67).

As activities are cut down into smaller pieces, possibilities for delocalizing portions of the service delivery chain arise. Still, the geographical distribution of KIBS activity is far from homogenous on both national and regional scales (Meri 2008 pp. 1-3 and 6). The relations of KIBS and KIPS firms with their clients are beset with asymmetries and uncertainties, largely due to the dynamically and unpredictably changing knowledge content of these exchanges (Strambach 1998 p. 4). The type and content of services requested by clients change dynamically as well; therefore the demand conditions require KIBS and KIPS firms to position themselves according clients' signals, which in turn amplifies their need for F2F contacts (Storper/Venables 2004 p. 64, Storper 1997 p. 239, Schamp et al. 2004 p. 621).

Some "traditional" agglomeration factors, such as urbanisation effects, linkages (both forward and backward) and labour market advantages lead to the agglomeration of KIBS in urban locations, and some authors claim that economically meaningful knowledge is relationally and territorially embedded in urbanised spaces (Coffey/Bailly 1992 pp. 863-866, Florida 2002 pp. 753-754, Storper 1997 pp. 236-241). Additionally the specific economic, technological and institutional conditions of individual locations co-influence the development of KIBS and KIPS, such as the existence of global firms' management operations (Stahlecker/Koch 2006 pp. 137-141). Along the vertical axis, forward-linkages to national manufacturing bases have important implications on the growth of KIPS firms and their location decisions (Guerri/Meliciani 2005 p. 499, Isaksen 2004 pp. 1171-1172). When establishing a permanent presence in all client locations is not feasible, other urban locations that serve as nodes of global air travel, highway crossroads and high-speed trains offer functional substitutes (Schamp et al. 2004 p. 614). Beside these forward links, knowledge-intensive producer services make use of inputs from diverse sources, which include services of other specialists, research institutions and government institutions, to name a few. Again, urban areas are often generally better endowed with such backward linkages and infrastructures (Coffey/Bailly 1992 p. 864). On the horizontal dimension, the screening and learning by observation advantages of localisation is apparent in the inclination of KIBS firms to co-locate in urban locations (e.g. Frankfurt am Main is the main location for investment banking) (Dicken 1998 pp. 414-415, Schamp et al. 2004 p. 611). To sum up, the reasons for KIPS firms to agglomerate spatially can be explained by the dynamics of knowledge production and knowledge-intense relations on the one hand, and with the basic mechanisms of spatial agglomeration on the other.

2.3. On technological and structural change

2.3.1. Long-waves of technological change

The transformation of human geographies in history is closely related with the technological capabilities human beings have developed. Technological change itself has been an ever-present process, although – according to the proponents of the long-waves theory – at a fluctuating pace. A wave-like character of macro-economic activity was suggested as early as 1901 by the Russian Marxist Pervus and it was other Marxist economists such as van Gelderen who put the idea forward (Eklund 1980 pp. 384-386). This section presents part of the discussions around the long-waves notion, which was put on the map by Kondratieff and Schumpeter in the first half of the 20th century.

Kondratieff's arguments were based on the long-term time-series in several economic indicators, mainly the movement of prices and interest rates. He claimed to have found a cyclical variation in data which suggested that crisis and recovery are inherent components of capitalist economy (Kondratieff 1984). The data he used was not without weaknesses, so Kondratieff himself was careful in his formulation: "On the basis of available data, it may be assumed that the existence of long cycles in economic conditions is very probable" (ibid. p. 89). His hypothesis attracted criticism at home in Russia and abroad for different reasons – the methodology, the soundness of source data, the deterministic-sounding findings and their political implications (Marshall 1987 pp. 24-25, Eklund 1980 pp. 394-401). These political implications were not warmly welcome in his newly founded communist country, because they suggested that – despite their post WWI troubles – capitalist economies would recover and rise again. This led to Kondratieff's arrest under fake charges and to his consequent disappearance in a gulag in 1930.

Although Kondratieff did not focus explicitly on technological revolutions and geographical developments, he did suggest two important points: "Before and during the beginning of the rising wave of each long cycle, there are profound changes in the conditions of the society's economic life. Those changes are manifested in significant changes in techniques (which, in their turn, are preceded by significant technical discoveries and inventions); in the involvement of the new countries in worldwide economic relations..." (Kondratieff 1984 p. 103). It was Schumpeter who emphasised the point about technological inventions in his writings on secular economic fluctuations and re-introduced Kondratieff to western economy literature by naming the long-waves "Kondratieff cycles" (Schumpeter 1939). The interest of Schumpeter in the cyclical-nature of the capitalist economic system arose partly from the deep economic crisis of the 1930's. During the boom years following the Second World War, long-waves were temporarily forgotten and cyclical tendencies were believed to be corrigible by Keynesian tools. As growth rates declined after the oil-crisis of 1970, long-waves discussion resurged and there were a series of important contributions in the 1980's (Freeman/Perez 1988, Mandel 1980, Perez 1983, Solomou 1986, Marshall 1987 among others). Lately, the interest in long-waves seems to have waned again.

Schumpeter saw the discontinuous clustering of basic technological innovations and entrepreneurial activity as the reason for cyclical fluctuations in economic activity

(Schumpeter 1939 pp. 84-109). He suggested three types of cycles with different durations and named them after the scientists who had studied them: Kitchins (short waves, about 40 months), Juglars (intermediate waves, between 8 to 9 years) and Kondratieffs (long waves, about 50 years). The long cycles Schumpeter suggested were close to Kondratieff's: the first from the 1780's to 1842 based on iron-smelting, steam power and the mechanisation of the cotton industry; the second from 1843 to 1897 based on the generalisation of the steam motor, railways and steel and the third from 1898 to the 1930's based on motorcars and electricity. Later authors suggest the existence of a fourth Kondratieff starting from the 1930's and lasting up to the new millennium, based on electronics and a fifth one based on IT technology is foreseen for the beginning of the new millennium (Hall/Preston 1988 pp. 151-261 and 284-288).

Schumpeter claimed that entrepreneurial endeavour causes a "swarm of innovations" that create material changes in production functions and affect the rate of investment in certain industries. His theory is that entrepreneurs dare to initiate new innovations and they manage to overcome the obstacles to make these business ventures successful. When they do succeed, a swarm of imitators are attracted and a broader diffusion of these innovations across economy takes place. The entrepreneur bears risks but is rewarded – if successful – with the awards society grants for such an innovation and but these get subsequently eaten away by competition and adaptation (Schumpeter 1939 pp. 104-105). With this rush to new areas of economic activity, older technology areas fall out of favour and are replaced by new practices, a process which Schumpeter calls "creative destruction" (Schumpeter 1939). After a period of growth, due to the absence of a general control mechanism, there would be excess investments in certain industries, the markets would overshoot the point of balance and a period of contraction and re-adjustment would ensue. This environment would in return motivate individuals with entrepreneurial energy to take on the risks to test new ventures.

It must be pointed out that Schumpeter clearly separated invention from innovation. Innovation was broadly defined by Schumpeter as "doing things differently" and as such it was not dependant on scientific novelty per se; and invention, or a radically new scientific advance, "does not necessarily induce innovation" (Schumpeter 1939 p. 84). In this context, it is innovation which is stimulated by the motivation of individual entrepreneurs acting as the endogenous factor which pushes long-waves and economic development (Marshall 1987 pp. 30-31). Schumpeter's hypotheses did attract criticism, most famously by Kuznets (1940). According to the latter, the scheme was too rigid and an explanation for the clustering of entrepreneurial activity in fifty-year spans was missing. Besides, Kuznets argued that it is very difficult to date the introduction of major innovations (ibid. pp. 262 - 271). Other studies supported this criticism and the long-waves discussion lost its sparkle for a period. However, interest was rekindled with the research on the pattern of technological change and development published by Mensch in 1979 (1975 in German) in an environment under the shadow of economic decline, if not crisis. Mensch claimed to have identified clusters of ‘basic’ innovations, which “are the source from which new products and services spring and in turn create new markets and new industrial branches to supply them” around the years 1770, 1825, 1885 and 1935 (Mensch in Mansfield 1983 p. 141, Marshall 1987 pp. 32-33). These dates precede the beginnings of the long-waves Schumpeter had announced previously and thereby Mensch answered one of the points of criticism to Schumpeter’s theory, namely the lacking evidence for the intensified innovation effort preceding expansion phases in economy. However, Mensch attracted his own critics who found his procedure for selecting and dating innovations subjective and arbitrary (Solomou 1986 p. 111).

While acknowledging the difficulty of classifying innovations, Freeman and Perez do suggest a taxonomy based on their characteristics and affects: incremental innovations (fairly continuous improvements, outcomes of ‘learning-by-doing’ and ‘learning-by-using’), radical innovations (discontinuous, result of deliberate efforts, potential springboards for new markets), changes in technology systems (far-reaching changes that affect several branches and give rise to entirely new sectors) and changes in ‘techno-economic paradigm’ (1988 pp. 45-47). The last are farthest-reaching in their effects as “they have a major influence on the behaviour of the entire economy” and consist of new technology systems, radical and incremental innovations. Here the changes go beyond the technological realm and affect input cost structures as well as production and distribution functions (eventually) throughout the world economic system.

Despite the fact that the regularity of technological revolutions is often contested, it is largely accepted that innovation flows have not been constant in time and that epoch-making discontinuities created by techno-economic paradigm changes deeply reshape economic activities and geographies (Kleinknecht 1990 p. 89, Storper/Walker 1989 pp. 199-202 and 206-208, Mansfield 1983 p. 144). Literature also suggests that for a new technological paradigm to be exploited, a new set of matching institutional environment (e.g. education and training system, industrial relations, managerial systems, capital markets and legal frameworks, among others) is necessary (Perez 1983 pp. 366-372, Freeman 1986 pp. 105-106). However, a discussion of the dynamics of these solutions and their transformation through technological paradigm changes is not a point of focus of this study.

Schumpeter claimed that the wave-inducing new technologies also set off a creative destruction process, in which established technologies are replaced by new ones. However, these revolutionary technologies also extend and improve existing technologies and sectors by stimulating co-inventions and having a transforming “general purpose technology (GPT)” effect. For instance, electricity not only led to the invention of the electric dynamo and electric motor. Consequently, electric motors transformed production processes technically and organizationally, eventually paving the way for Henry Ford’s assembly-line, which could not have been implemented as easily with steam powered power-shafts. In its turn, the rise of the motor car gave a huge new application area to steel, which was one of the drivers of the previous wave.

As mentioned before, IT is claimed to be the spark of a new long-wave (Hall/Preston 1988 pp. 284-288). It is also perceived to be a transforming GPT, whose defining nature is the soft complementarities with social structures and other technologies it develops (Fernald/Ramnath 2003). For instance, in the late 1980’s it was predicted that there was a huge potential for the automotive industry to gain from electronics and IT technologies. As discussed later in the next section of this study (2.3.3), this projection did eventually materialize (Marshall 1987 p. 232) and IT does create significant gains in the performance of older technology areas. Elsewhere, Fernald and Ramnath describe how the services sector manages to achieve productivity gains due to successful IT applications with the example of Wal-Mart (2004 pp. 58-61). The positive productivity growth effects of ICT on the macro level and on the services sector has also been documented (Anderssen 2006 p. 208).

2.3.2. Regional structural change, path dependency and “lock-in”

One of the prominent changes in the world’s economic landscapes is the deindustrialisation phenomenon. Although it is used relatively loosely by different authors, it can be defined principally as “a relative decline in industrial employment in a nation or region where industry has traditionally been a significant component of the economy” (Knox/Agnew 1998 p. 5). Manufacturing employment has indeed been on a continuous downward path since the beginning of 1970’s in developed countries (i.e. United States, EU-15 and Japan). Naturally, the respective beginnings and the extent of deindustrialisation have not been identical, but during the same period, the services employment in these countries rose persistently (Rowthorn/Ramaswamy 1997 pp. 7-9).

An explanation suggested for this shift is the divergent labour productivity growth rates between these two sectors. The faster productivity growth in manufacturing is claimed to have reduced the relative need for labour, while services maintained its own growth. A similar productivity growth in agriculture had accompanied the shift of labour from former to industrial activities. The reason for productivity growth in manufacturing can be explained with the introduction of process improvements, enabled by innovations brought by the new long-wave. In other words, the fourth Kondratieff, which was based on electronics technology, transformed the Fordist production technology and relations, allowed more efficient and flexible production systems and gave rise to new industrial structures (Dicken 1998 pp. 436-437, Coffey/Bailly 1992 p. 858).

Geographically, the most visible deindustrialisation phenomenon was observed in regions that had previously specialized most in Fordist industrial manufacturing. The consequences of the transformation for these regions, e.g. Mid-Atlantic areas in United States or Ruhr region of Germany, have been disastrous (Knox/Agnew 1998 p. 238). Needless to say, the deindustrialisation of old industrial areas cannot be explained through Kondratieff cycles only. For instance, product-lifecycle based arguments claim that when a region fails to switch to a "growth" industry as the existing one enters a mature phase, it will fall victim to the eventual price competition with peripheral locations (Steiner 1985 pp. 393-394).

These drastic examples of regional decline can also be explained with reference to the notion of regional "lock-in." As such, lock-in is actually a particular form and outcome of path-dependence. Path-dependence itself states that "history matters" and initial and existing conditions co-shape present and future socio-economic and technological developments (Hayter 2004 p. 104). For instance, according to Porter clusters form in places with already existing industries and capacities (Porter 2000 p. 27). The self-reinforcing and self-producing group of locational factors does not necessarily induce negative effects. They become destructive for localities when they restrict them from absorbing new technologies, views and practices.

In economic activity, three major and somewhat inter-related types of lock-in are to be suggested: technological (the tendency of technological fields to be locked into a path, although possibly more efficient alternatives are available), dynamic increasing returns (caused by various externalities and learning mechanisms that operate to produce positive and cumulative feedback effects) and institutional hysteresis (tendency for formal and informal institutions, social arrangements and cultural forms to be self-producing and restrictive in time) (Martin/Sunley 2006 pp. 399-400, Arthur 1989 pp. 126-128). Social, political and economic factors can reinforce each other interactively to lock firms, sectors and regions on to certain trajectories (Hayter 2004 p. 104). They can lead to restrictive regional technological regimes (sometimes in connection with sunk costs in capital and knowledge assets), regional externalities and institutional environments that restrain necessary evolution or a path-change in a location. An example is to be found in Grabher's account of the Ruhr area in Germany where he speaks of "functional" (based on inter-firm relations), "cognitive" (common orientation and world-views) and "political" (the institutional structures) types of lock-in (1993 pp. 260-264).

Regions can break free of the paths they had been locked-in or can prove themselves to be capable of renewal and transformation. Chance and chance events seem to have a "liberating" effect on the evolution of localities. These arbitrary or seemingly random factors can cause a region to pursue new variations on an existing path or to switch to an altogether different path when specific characteristics of the regional environment are supportive (Boschma/Lambooy 1999 pp. 421-424). Crises are also claimed to be a factor in such a path-departure in that they trigger reformulation of habits, routines, conventions and policies. War and periods of economic recession are examples to this end (Hayter 2004 p. 106).

Certain regional characteristics are suggested to increase the adaptive behaviour of locations, making them more responsive to environmental change and self-transformation. Network-based production systems, diversity (as in heterogeneity among agents, technologies, institutions and social networks) and transplantation (diffusion of imported new forms, technologies and industries…) are among the mechanisms that can help a region to avoid negative path-dependency (Table 1). However, the discussion on the exact nature and dynamics of these regional transformation scenarios still has unanswered questions in store. Public policies can also assist regions in avoiding lock-in cases. The role of public policy in the first place should be to ensure that regional industries remain responsive to changes in the global techno-economical environment and to support an innovation and learning friendly institutional climate. Yet, once industrial decline sets in, it is very difficult to change its course. At that point, the effect of public initiatives depends on the strategy-problem match, the state of the regional industry at the start of public intervention and partly on the age of the region (with younger regions being more open to policy impact) (Storper 1997 pp. 275-280, Sternberg 1996 p. 83).

Table 1: Possible scenarios for avoiding regional lock-in

Sources of new path	Characteristics
Indigenous creation	Emergence of new technologies and industries from within the region without antecedents there
Heterogeneity and diversity	Diversity of local industries, technologies and organizations promotes constant innovation and economic reconfiguration, avoiding lock-in to a fixed structure
Transplantation from elsewhere	Importation of a new industry or technology from elsewhere, which then forms the basis of path of growth
Diversification into (technologically) related industries	Transition where an existing industry goes into decline but its core technologies are deployed and extended to provide the basis of related new sectors in the region
Upgrading of existing industries	Revitalisation and enhancement of a region's industrial base through the infusion of new technologies or introduction of new products and services

Source: Martin/Sunley 2006 p. 420

2.4. Research questions, explanatory model and working hypotheses

In a broad sense, this study aims at contributing to the understanding of the meaning of spatial proximity. One of the questions that businesses, academia and policy makers ask themselves in today's globalised, digitalised, post-industrial and knowledge-dependant world is: can spatial proximity be substituted with a mix of technological and social innovations (e.g. increasingly powerful ICT tools and personal mobility)? Or, in other words: is geography really dying? This study does not hope to answer this question in its entirety, but would like to make a worthwhile contribution. An answer in this context will be sought by focusing on knowledge-intensive producer services and by turning to knowledge-production and aspatial proximities discourses (Section 2.1).

From the preceding literature analysis a series of research questions and hypotheses have been formulated. Answers to these questions will be sought within the realm of the specialized software services around the Stuttgart automotive cluster.

Research question I

What is the relation between the knowledge content of producer services and their spatial proximity requirements?

Research question II

What is the relation between spatial and aspatial (social, organizational, institutional and cognitive) proximities for knowledge-intensive producer services?

Research question III

What role is played by regional lead firms for knowledge-intensive producer services activity?

Research question IV

What can be inferred from the case of knowledge-intensive producer services for the discourse on regional structural change?

The aspatial proximities discourse discussed in Section 2.1.3 offers a new way of seeing the spatiality of business activities. Therein Boschma puts forward a multi-layered approach that offers a potentially interesting tool to analyse the knowledge-intensive business relations. This study will adopt Boschma's framework as part of a dual-layered research approach that links micro and macro levels of inquiry. Esser suggests and explains such a dual-layered research concept for analysing sociological phenomena (Fig 9).

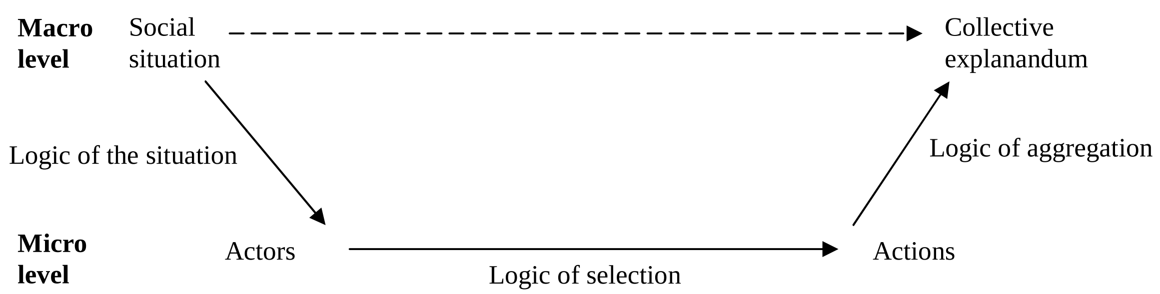

Fig. 9: The basic model of explanation for sociological phenomena

Source: Esser 1999 p. 98

Here the collective explanandum, the macro-level case to be explained, is an aggregated outcome of the behaviours of actors at the micro-level under macro-level conditions for the given social situation (ibid. pp. 93-100). Starting with the macro-level boundary conditions ("social situation"), the "logic of the situation" pre-defines the stipulations for actors and the alternatives available for them. With the "logic of selection", actors and social behaviour come together at the micro level. The actors select certain actions among alternatives with certain expectations and assessments. The aggregation of these actions in return transforms the macro-level conditions. The investigation of the processes involved here help explain the macro-level phenomena. In the specific example of this study, the phenomena of the agglomeration of software service firms around the automotive cluster represents the macro-level explanandum as a result of the decisions of automotive firms for certain software services suppliers and the latter group's decision to locate near automotive firms (behaviours). These decisions are outcomes of actions at the actor-level, which take place under social and economic boundary conditions.

On the background of the literature survey provided in the preceding pages, the following hypotheses are deducted. These do not build on each other in any way and indeed some actually point in divergent directions.

Software-services for automotive industry are basically knowledge-intensive producer services that are closely dependant on the interaction with customers (Section 2.2.5); Functioning clusters entertain active traded and untraded exchange relations that stimulate interaction (Sections 2.2.2 and 2.2.3). The sector-specific and novel knowledge is often tacit in form and the exchange processes involving tacit knowledge are resistant to geographical distance (Section 2.1.1).

Hypothesis I: The presence of a geographical agglomeration of customers is a reason for specialized software firms to locate near existing industrial clusters.

Hypothesis II: The interaction with customers stimulates the innovativeness of software services firms.

Hypothesis III: Customers who are geographically proximate are stronger innovation stimulators for software services firms.

Hypothesis IV: As a software services firm grows in size, the role of geographically proximate customers for innovation diminishes.

The automotive industry is under extreme cost and complexity pressures and automotive manufacturing supply chains operate in a globally-dispersed manner. Especially in developed countries, market success and survival of OEMs and suppliers depend on product and process innovations (Section 4.1). The automotive sector is heavily capital-intensive and intra- and inter-firm processes have strong dependencies across the activity chain. Therefore, a disturbance in a single step of the chain can have extensive financial consequences.

Hypothesis V: For automotive firms, skills and service quality would be a more important criterion than geographical proximity for selecting software services suppliers.

Hypothesis VI: In order to prevent risks associated with new business partners, automotive firms would value trust-based long-term relations with software suppliers.

Hypothesis VII: With English as the established working language and converging regulatory frameworks across trade-blocks such as the European Union, institutional proximity appears to be a negligible criterion.

These hypotheses refer predominantly to micro-level issues. The chosen explanatory approach (Fig. 9) involves accumulating and processing micro-level data to come at macro-level explanations. However, the limited availability of data restricts the possibility of a satisfactory reflection on macro-level matters, hence macro-level hypotheses. Before a discussion of the empirical research carried out in Stuttgart region follows, the next sections presents the empirical methodology that has been adopted for this study.

3. Methodology for empirical data collection

3.1. Research approach and implementation

The starting point of research builds on the framework and arguments derived from existing theories on proximity relations, regional agglomeration and structural change realms. On this background, the chosen model of explanation utilizes both quantitative and qualitative resources for its purposes. For the quantitative side, secondary data from official statistical sources have been used. However – as described in the coming pages – the depth of analysis here is limited by the (un)availability of data. Besides, the research questions and the hypotheses to be tested address highly ingrained social processes, which do not lend themselves readily to quantitative means of research. For this reason, qualitative data gathered through in-depth expert interviews will form the basis of analysis. The next section "Data Resources" provides a more detailed presentation of respective data resources and methodology.

The presentation of the empirical analysis begins with a comprehensive presentation of Stuttgart region and the respective analyses of regional automotive and software service sectors. This is necessary in order to underline why Stuttgart region is a suitable location for the research questions and why the findings shall be generalized with a degree of caution. Thereafter, the analysis based on the collected primary data is presented with reflection on the theoretical background. The study is completed with a summary of the findings within the context of the research questions and with respective reflections for policy and research fields (Fig. 10).

- The reflective presentation of the relevant theoretical background of this study.
- Conceptualisation of the research questions, hypotheses and an associated explanatory model.

- Collection of corresponding secondary data.
- Evaluation of secondary data and the identification of candidates for in-depth interviews.
- In-depth interviews and their evaluation.

- Presentation of the results within the framework of research questions.
- Presentation of a summary of results with respect to research questions, verification of hypotheses and reflection for policy and research realms.

Fig. 10: Methodological approach

Source: Own representation

For the purposes of this study, software is considered a service, rather than a “symbolic product” or “intangible good” (Miles 1996 p. 243). More specifically, automotive-oriented software applications are aimed at the commercial (or enterprise) user domain and are therefore classified within intermediate or producer services (Section 2.2.5). At the same time, considering the combination of knowledge and technology contained in the equipment, processes and personnel on client and supplier sides, software services for automotive industry can safely be considered to be within the realm of knowledge intensive producer services (Hauknes 1999 pp. 6-8). These services correspond to other characteristics of KIBS as suggested in literature as well. Beside their own innovative capacity, automotive-oriented software services[12] stimulate knowledge-production in their clients’ operations and help the distribution of best-practices among their clients. Simulation and virtual reality software applications are examples of how software tools and services modify and improve product development processes in the automotive industry and assist a continuous production of product and process knowledge. On a similar note, taking Dosi’s definition of innovation as a reference, these services can be accepted as innovative-inducing and knowledge-producing (Dosi 1998 p. 222, Section 2.1.2).

[12] In the remaining part of this study, the terms “software services for automotive industry” and “automotive-oriented software services” will be used interchangeably.

For this study, software services for automotive industry are defined with reference to two selected application domains of the software applications and services. The first one covers the services activities that assist the development of the software applications installed on motor vehicles and their components. Such software applications are very often specially designed and developed for dedicated automotive use; hence software services to this end can be classified as "automotive-oriented" without much difficulty. The second group of services refers to process-oriented software applications that are developed or adapted for the needs of the automotive sector. Although the task of categorizing appears more challenging, target-market specificity of the services can still be identified and adopted as a criterion for automotive sector orientation. Coming from this angle, the relatively more "generic" enterprise IT-applications, such as communication, eBusiness and project management tools, will be excluded from consideration. In contrast, software applications used for vehicle development, e.g. product and production engineering, display considerable automotive-orientation. Some of these tools are developed exclusively or primarily for the automotive industry, yet even more others are comprehensively-modified derivatives of general-purpose applications.

For the discussion of aspatial proximities, the multi-layered model suggested by Boschma will be adopted as the main template for the analysis of knowledge intensive producer services between the automotive and software sectors (Boschma 2005). Despite their sophistication, alternative concepts and constructs on aspatial proximities (e.g. organizational or relational proximities) lack the clarity of Boschma's model in dissecting and analysing different social factors that affect knowledge-intensive relations (Section 2.1.3).

3.2. Secondary data resources

The statistical data published by the German Federal Statistics Office is the primary basis for aggregated secondary industrial data. In addition, the 2005 and 2007 issues of the comprehensive report "Strukturbericht Region Stuttgart" (Structural Report – Stuttgart Region) and specific employment data acquired from the Federal Employment Office have been utilized as complementary sources of secondary data and analysis.

About automotive sector statistics

The characteristics of Stuttgart region and Stuttgart automotive cluster will be discussed in Sections 4.2 and 4.3 to present the regional and sectoral background on which the software services for automotive industry are operating. For this purpose, the statistical group "Manufacture of motor vehicles, trailers and semi-trailers" (Classification group of 34 in

ZW2003 and NACE Rev. 1.135) will define the boundary of sectoral data. Three main groups of activities are included in this group: “the manufacture of motor vehicles” and “the manufacture of bodies (coachwork) for motor vehicles, “the manufacture of trailers and semi-trailers” and “the manufacture of parts and accessories for motor vehicles and their engines.” As such, the data resources capture vehicle manufacturers and their immediate suppliers statistically, yet other firms which carry out production and services activities that are directly linked with the automotive sector are listed elsewhere. In industrial reality, certain specialized machinery manufacturers (e.g. press-makers), plastics components suppliers and some knowledge-intensive services activities (e.g. engineering and development services agencies) shall be considered within the dense fabric of automotive industry in the region as well. Enterprise services of lower technological complexity, such as facility management and increasingly significant staffing services are also related to, but not markedly dependant on, the automotive cluster.

An alternative source of enterprise information is the relatively new Business Register databank, which is also maintained by the Federal Statistics Office. One of the main objectives of this databank is to capture the actual number of active enterprises in German economy and for this purpose it utilizes a series of different resources and includes businesses on the basis of their liability for tax, rather than on the basis of their staff levels. At the regional level, Business Register only publishes the numbers of firms and employees, but not revenue data due to non-disclosure concerns. For the allocation of enterprises in respective statistical groups, Business Register considers the actual revenue structure of the enterprises rather than solely depending on firms’ own declarations (which is what standard statistical records do). Therefore, Business Register tends to report larger number of automotive enterprises compared to other official statistics, because automotive suppliers, which would otherwise be listed elsewhere (e.g. plastic parts producers), are counted in the Group 34. Although it fulfils the source quality criteria suggested by European Statistical System, Business Register is not an ideal source to make comparisons between the years (Sturm/Tümmler 2006 p. 1021). This is largely due to the fact that it is still continuously being improved in terms of its data resources. This study values the data provided by standard statistical resources and Business Register to present a more detailed picture of the regional automotive industry.

About software services sector statistics

Software-related services activities relevant for this study are statistically classified under "computer and related activities" (Classification group of 72 in ZW2003 and NACE Rev. 1.1). Therein, "software consultancy and supply (72.2)", "data-processing (72.3)", "database activities (72.4)" and "other computer related activities (72.6)" are considered. The two other sub-sections under classification group 72, "hardware consultancy (72.1)" and "maintenance and repair of office, accounting and computing machinery (72.5)", lie outside the focus of this study. However, such a detailed selection restricts the availability of statistical data at the regional level. At the chosen geographical level, viz. Stuttgart region, there is no data available from the Federal Statistics Office for the respective three digit sub-groups due mainly to non-disclosure concerns. The Business Register database does deliver the number of firms and employees for the chosen details but available data date back to only 2003. Besides, as it is the case with other official statistics, Business Register does not provide any statistical basis as far as the market-orientation of software firms is concerned. On this background, a detailed data basis on the software services industry in Stuttgart region is not available.

As complimentary sources, MARKUS databank and the databanks of the Chamber of Industry and Commerce of Stuttgart Region (IHK databank) and the chamber of commerce network of Baden-Württemberg (IHKBW databank) were employed. MARKUS databank is maintained by the credit agency Creditreform and the publishing house Bureau van Dijk Electronic Publishing. It contains business information regarding enterprises from Germany, Austria and Switzerland. The data for German enterprises is collected and maintained by Creditreform based on the national trade register, direct contacts per telephone and post, yearly reports, daily newspapers and further data resources. Although it is not an official resource, MARKUS databank is continuously updated and rigorously maintained. As of July 2008, MARKUS databank holds 886.000 German enterprises. But its strategy of data collection and classification differs from official statistics. For instance, due to trade registry regulations, the inclusion of smaller enterprises in MARKUS databank is largely sector and size dependant.

Both IHK databanks include information regarding the members of the regional chambers of commerce in Stuttgart and Baden-Württemberg. In MARKUS and IHKBW databanks, search functions that allow the use of geographical and sectoral criteria are available. Both display areas of activity of enterprises according to ZW2003 and NACE Rev. 1.1 in three-digit depth.

In contrast, IHK databank for Stuttgart region offers a self-defined classification entitled “media and communications businesses” and is a sub-group called “software and IT-services.” However, the exact details of the activities included are not explicitly defined.

However, all three non-official databanks place enterprises in classification groups according to the data available to them and at their own decisions. Consequently, there are discrepancies between the statistical numbers published by MARKUS and IHK databanks and Business Register. For the four sub-groups of classification (ZW2003 72.2, 72.3, 72.4 and 72.6), Business Register reports 2872 enterprises as of December 2006, while MARKUS databank cites 1202 firms as of July 28th 2008 and IHK databank refers to 1253 firms as of July 27th 2008. Both databanks offer search possibilities within the activity definition for individual enterprises. However, these definitions are provided by firms themselves and vary greatly in terms of content. This is therefore not a reliable tool to identify the total number of automotive-oriented software services firms. On the other hand, the IHK and IHKBW databanks do report certain numbers of firms in response to searches for keywords such as “automobile, automotive and vehicle”, but contrary to expectations, these numbers do not match between the two linked resources. A combination of the results from both sources results in a list of 40 enterprises. Therefore, these three resources can only assist this study as far as identifying possible partners for in-depth interviews is concerned, but not by establishing the total number of firms offering software services for automotive industry.

3.3. Primary data resources

As discussed in Section 2.5, the data collected at the actor-level will be analysed to explain the role of aspatial proximities in the behaviour of automotive and software services enterprises. The aggregation and interpretation of this data would consequently assist the explanation of the agglomeration tendencies of producer services activity. The chosen method of data collection for all groups was qualitative semi-structured in-depth expert interviews. In comparison to the standardised interview method, which excels in statistical generalizability and replicability, qualitative interviews are more suitable to understand actors’ behaviour in environments of technological, social and economic change (Schoenberger 1991 p. 180). The predominance of open-ended questions in this type of method gives the implementation a flexibility that helps to identify and extract the constraints and possibilities that affect mechanisms of behaviour (Scholl pp. 66-67). While the existing theoretical background provided the backbone of the central inquiries chosen for the interview, it was also tested and extended by statements from the interview partners. During the interviews for this study a combination of deductive and inductive approaches was adopted.

A total of 32 experts were interviewed for this study, who were representatives of automotive and software firms, as well as regional experts from industry and academia. Several resources were utilized in order to identify and acquire regional experts. The data collected from IHK database provided a starting point for possible candidate firms. As an additional source of contact, the virtual networking platform Xing[13] was employed. Here professionals from automotive and software sectors, whose self-declared interests relate to software development and services for automotive industry, were identified with the help of the integral search function and they were contacted accordingly. Further personal contacts made at sector-specific symposia and conferences as well as personal networks also helped to identify and win interviewees. In all cases, the selection of interview partners was not conducted through random sampling. Instead, the aim was to create a diverse and heterogeneous group of interviewees from the broadest possible areas of relevant activity (Fig. 11).

The relevance of the interview partners was ensured through the selection strategy. For the automotive sector, different and relevant organisational and technical sections of the value chain (e.g. pre-development and development; in-product and process-oriented software applications) were addressed and persons at management capacity that purchase software services from outside providers were selected. The experts from the software sector belonged to enterprises with diverse portfolio of services in terms of technological content, business models and degree of automotive-orientation. Moreover, in six cases it has been possible for the study to win experts with matching tasks and responsibilities in highly identical areas of activity in different automotive and software enterprises. This allowed for a higher relevance and validity of findings. Overall, the method made it possible to collect and aggregate a broad set of insights relating to behaviours of actors. No differentiation in terms of nationality or ownership was considered for the selection process.

The workplaces of all interviewees are in Stuttgart region, except two who were employed at Audi AG operations located in Neckarsulm, which is located in the neighbouring Heilbronn. As it will be mentioned later in this study, the Audi-Neckarsulm entertains links with the

[13] This networking platform can be accessed at: www.xing.com. Descriptive information about Xing is available at the following interview: Kiss, Jemima (2008). *Elevator Pitch: Xing battles for pole position in professional social networking*. [Online]. Guardian, online edition, 7th May 2008. Available from: http://www.guardian.co.uk/media/pda/2008/may/07/elevatorpitchxingbattlesfo [Accessed: 17th September 2008]

Stuttgart automotive cluster and software firms located in the region[14]. The operational and spatial closeness of Neckarsulm to Stuttgart region and the additional value these interviewees contributed to this study justified the inclusion of these interviews in the primary data set.

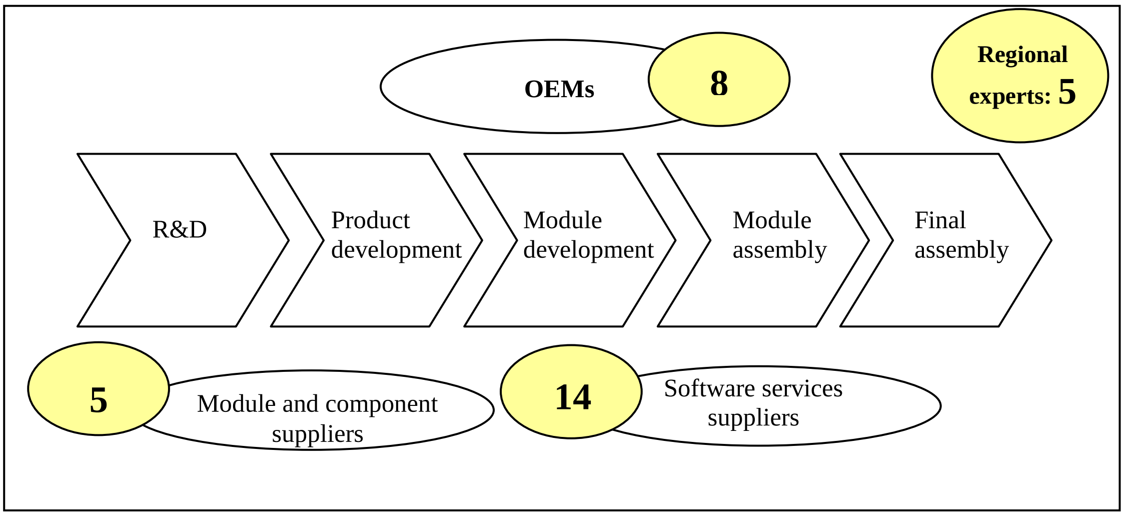

Fig. 11: The distribution of interviews partners according to areas of activity

Source: VDA 2004 p. 12 and own representation

The average duration of an interview was approx. 40 minutes, but in several instances this time was considerably exceeded. The interview language was predominantly German and nearly all interviews were digitally taped and consequently transcribed. Only one interview was conducted in English and two interviews were recorded by simultaneous transcription.

For interviews with automotive and software services firms, two distinct sets of questions were deployed. The outline of the interview questions was adapted to the case presented by the expert and his field of activity. Therefore the study does not have a single questionnaire, but a group of organically linked question sets. For this reason, a complete list of interview questions will not be presented in the annexes. Apart from those regarding the expert's background and area of activities, the main questions for interviews with automotive firms were the following:

- What is the role played by software applications for the operations of your area of responsibility?
- Which software services do you purchase for your department? Which applications do you choose to maintain in-house?

[14] The first contact to Audi representatives took place during an event organized by a Stuttgart-based software enterprise.

- What reasons lead you to externalise software services?
- Has your behaviour to outsourcing software services changed in time?
- Which factors and criteria play a role in your choice of software services providers? What role does geography play?
- Does geographical proximity bring advantages for your relations with software services suppliers?
- Do you have a strategy to build long-term relations with your software services suppliers?
- Do you follow a conscious strategy to motivate your software services suppliers to improve?

For software services firms, the following group of questions constituted the main line of inquiry:

- Why did you choose Stuttgart region as a location for your company? Was the existence of an automotive cluster a factor?
- What proportion of automotive companies, both manufacturers and suppliers, is in your client portfolio in terms of number and turnover?
- How do your interaction and business relations with your customers from the automotive sector affect your product and service related processes and decisions? Do you think your customers contribute to your innovativeness?
- Does the location of the customer affect your interaction and business relations with them?
- How did your firm establish its knowledge and skill base and how do you maintain it?
- What kind of effort do you invest when you start a new project with a customer? Does the necessary effort change with a new customer?
- How do the lead firms in the region affect the development of the local software services sector?
- Have the geographical reach and links of your company changed as your company grew?
- Do you have contacts with other software firms in and outside of Stuttgart region? What is the nature of these contacts and have you engaged in cooperative projects with them?

3.4. Reasons for choosing the Stuttgart region

The economic fabric of Stuttgart region has been experiencing a shift from manufacturing to services (related and unrelated to production activities), albeit at a slower rate than in the rest of Germany and Europe (Section 4.2). The automotive and machinery manufacturing sectors are still strongly present and both display export-fuelled growth numbers. However, the business services sector is also growing at the same time at a healthy rate. In this respect, Stuttgart is one of the most suitable locations in Europe to observe the co-presence of production and services functions and furthermore to analyse the interaction between production activities and producer-services. In terms of the sectors chosen for this investigation, that is automotive and software services, Stuttgart region again presents a rare and appropriate picture.

Two significant and technology-oriented OEMs, Daimler and Porsche, and numerous large automotive suppliers such as Bosch, Mahle and Behr have their headquarters and R&D centres in the region. The knowledge-intensive nature of the regional operations of these firms is one of the drivers of the demand for sophisticated producer services. The expensive cost base of South Germany motivates automotive firms to operate tightly managed, efficient and sophisticated internal and external processes, which is only possible by using competent software applications. A sign to this end is the steadily increasing number of IT-related jobs at automotive enterprises. Similarly, the growing number of persons with automotive-engineering related degrees working for software firms also suggests an increase in the delivery of software services for automotive industry in the region. The region is endowed with the necessary elements to speak of an automotive cluster and the automotive oriented software services activity hints at the existence of a sub-cluster as per Porter’s definition. As such, Stuttgart region is an appropriate geographical research area to investigate the localized knowledge intensive and knowledge-producing relations in a region of structural change.

4. EMPIRICAL RESULTS

4.1. Contextual background: the automotive industry today

After going through decades of evolution, the automotive industry continues to be of consequence, not only because of its social, technological and environmental impacts, but also for its vast economic presence. According to numbers published by OICA, International Organization of Motor Vehicle Manufacturers, the direct employment in vehicle and parts production in 39 vehicle and component producing countries was slightly lower than 8.4 million in 2004. In 2005, the global automotive industry produced an estimated 66 million cars and commercial vehicles; creating a turnover of €1.9 trillion. The provisional production numbers reported by OICA for 2006 foresee an increase of 2.6 million units to more than 69 million. The role of EU-27 therein is clearly substantial, with an estimated 30% share in global passenger vehicle production in terms of units[15]. As for total value added, EU-15 countries matched US at around €114 billion in 2002.

Automotive maintains strong backward linkages and affects not only sectors producing physical goods, but also business services. According to ACEA, European Automobile Manufacturers Association, automotive creates five times its employment in indirectly related manufacturing and services provision activities. In EU-27, direct automotive employment was around 2.3 million in 2004, with another 10 million individuals working indirectly for the industry[16]. Most of the motor vehicle assembly locations in the European Union are found in central and central-western Europe, with further locations in Spain, Portugal, Italy and Turkey. Although Germany, France and Spain manage half of the European production between them today[17], forecasts point in the direction of BRIC countries (Brazil, Russia, India and China) for future growth and expect them to narrow the gap to the established automotive locations in North America, Europe and Japan.

The enlarged Europe, though, has been enjoying a fresh-breath of locational advantages in central and east European countries. Largely due to this reason higher growth rates are foreseen for automotive industry in Europe in comparison to North America and Japan (Mercer 2007 p. 93). On a similar note, the expected growth in European production capacity is actually believed to be due to central-eastern countries like Slovakia, the Czech Republic and Hungary. On the other hand, BRIC countries, especially China and India, come forward with an intriguing mixture: cost advantages on the supply side (lower labour rates, more flexible working arrangements due to lower unionization and green-field facilities with newer

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[15] Source: The European Automobile Manufacturers Association (ACEA) (2007). *Production - Key Figures*. [Online]. Available from: http://acea.thisconnect.com/index.php/files/statistics_motor_vehicles_production_summary_2006 [Accessed: 29th Nov 2007].

[16] Source: The European Automobile Manufacturers Association (ACEA) (2007). *European Motor Vehicle Industry - Key Figures*. [Online]. Available from: http://www.acea.be/images/uploads/doc/463-8.pdf [Accessed: 6th March 2007].

[17] PricewaterhouseCoopers (2006a). *European light vehicle assembly growth to be driven by Central Europe*. [Online] Available from: http://www.pwc.com/extweb/ncpressrelease.nsf/docid/16C22C3385BE2AF1802571B000639CE9 [Accessed: 6th February 2008].

technology) coupled with a booming demand for new vehicles thanks to rising prosperity and growing middle-classes[18].

Before discussing technological and structural issues, it is necessary to mention the topic of consolidation in the industry. Starting with 1980's, the OEM[19] market saw a continuous tide of mergers and acquisitions (M&A) that consolidated and globalized the industry in terms of capital, organization and production[20]. While the number of vehicles produced increased, these were produced by an ever smaller number of groups that own different car brands[21]. The products of these different brands are built on shared sets of vehicle architectures or so-called platforms and modules. Modules refer to groups of related components and systems serving for the same or connected tasks, i.e. the front / rear axle, complete front-section of a body or the steering system. Interrelated modules constitute the platforms, on which products for different car brands are developed. This sharing of components is crucial for reducing costs, as 60% of the production costs of a vehicle are allegedly sunk in its platform[22]. During the same period, OEMs reduced their number of direct suppliers, and persuaded their suppliers to be more involved in product development. Today, OEMs outsource not only the manufacturing, but also the development of complete modules to suppliers across the several brands they own. Therefore, large suppliers today compete for a smaller number of contracts (of larger size) that bear higher risks and financial strains. Besides, OEMs demand that their suppliers deliver components to different global locations on a just-in-time basis, which means setting up shop globally. Under such pressures and risks and faced with ongoing structural change, consolidation has been a continuous phenomenon among suppliers for more than decade now and their number is expected to be halved to 2800 between the years 2000 to 2015 (Sutherland 2005 pp. 240-244, Mercer 2007 p. 90).

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[18] PricewaterhouseCoopers (2006b). *BRIC to Account for 40% of Auto Sector Assembly Growth*. [Online] Available from: http://www.pwc.com/extweb/ncpressrelease.nsf/docid/E6840EEEFB69F4CC802571EF004D6467 [Accessed: 6th February 2008].

[19] In industry-speak, automotive manufacturers are named "OEMs", as an acronym for Original Equipment Manufacturers.

[20] Some of the mergers applauded by the business press in their time failed to produce the prophesied results. The cases of Daimler-Benz/Chrysler Corporation (1998-2007) and BMW AG/Rover Group (1994-2000) are two high-profile examples. Due to these fresh memories, joint ventures and project based partnerships appear to be the preferable option as compared to car-makers over outright M&A activity lately.

[21] For instance, the car brands in VW Group include: VW, Audi, Skoda, Seat, Lamborghini, Bentley and Bugatti.

[22] According to Prof. Dr. Martin Winterkorn, Chairman of VW AG, quoted in *Automobilwoche* (3, 28th January 2008, p. 27)

Post-Toyotaist period?

In order to comprehend the organisational and technical division of labour and the structural basis of today's automotive industry, two organizational concepts that deeply changed the industry, Fordist production techniques and Toyota's lean manufacturing approach, need to be mentioned here. Fordist methods, which were based on Taylorist principles, turned an adolescent and fragmented handicrafts-based activity into an epoch defining industry that introduced production-line and mass-production relations. In basic terms, Taylorist management principles sought perfection in tasks by separating and isolating them from each other, which also led to the separation between physical and intellectual labour (or as it were between hands and brain). This resulted in hierarchical intra-firm structures built on supervision, measurement and reward (West 2000 p. 7). Hierarchies extended to inter-firm level relations, instituting price-based, arms-length relations between manufacturers and suppliers. In effect, the onus was largely on OEMs for product design and development. Suppliers entered the stage at a later phase to undertake the production of pre-designed components (Womack et al. 1990 pp. 140-146). Even then, most OEMs had a very high production depth compared to today's manufacturers.

Toyotaism originates from the Japanese-style management principles most aptly implemented by Toyota Motor Company. The concept, which later branched out into the more generic lean manufacturing approach, aims to increase productivity and quality through eliminating all activities and items that do not add value to processes and products (Liker/Morgan 2006 pp. 5-6, Graves 1996 p. 215). Team-based work is a fundamental principle of the organizational innovation of Toyotaism, with all members able to carry out numerous tasks and employees even keenly encouraged to suggest product and process improvements (hands meet the brain again) (Womack et al. 1990 p. 99). In this new picture, OEM-supplier relations operate in a very different manner. Suppliers are involved in design processes from an early stage and the trust-based sharing of knowledge is the norm. In inter-firm relations, the accent is not only on price, which undoubtedly remains crucial, but also on quality, reliability and experience-based reputation (West 2000 p. 15, Womack et al. 1990 pp. 146-148). Clearly, compared to the distanced relations in the Fordist approach, the Toyota system depends on closer ties between suppliers and their customers, to the extent that they are a *fundamental* part of the OEMs' product development system (Liker/Morgan 2006 p. 14). Consequently, this depth of cooperation and knowledge sharing produces interactive learning effects for both sides and supply relations cease to be dominated solely by price-negotiations.

As such, the Toyotaist model reminds firms and firm networks of the effects of economies of speed. In Anglo-Saxon literature, the notion of economies of speed was initially popularized in Chandler's writings on enterprise management structures of modern cooperations (Chandler 1999 [1977] p. 235). Chandler argued that the more elaborate division of labour inside an enterprise across units and consequent intra-unit specialisation caused interdependencies between activities and increased the importance of coordination (Chandler in McGraw 1988 pp. 401-403). Successful coordination created economies of speed in operation which helped the enterprise to exploit its capital and processes more effectively. In other words, Chandler pointed out that the success of an enterprise depended not only on the scale with which it produced goods, but also on the speed with which it ran processes. Today, for the vastly globalized and technology-oriented industries like automotive, the emphasis on speed economies has shifted to faster innovation and delivery, while simultaneously seeking scale and scope economies (Ito/Rose 2004 p. 64, Granstrand 1998 p. 474). In addition, at inter-firm and network levels, there is interdependency between economies of speed and network effectiveness and efficiency. Networks that manage to capture and exchange knowledge faster across their members are successful in achieving speed economies that lead to advantages over peers. Such network efficiencies are closely linked to intra-firm processes and as such, what the Toyotaism approach seeks to provide resembles speed economies at intra- and inter-firm level for the automotive industry development and production networks.

Today, signs of Toyotaist thinking are easy to identify: on the one hand, lean manufacturing principles are the de facto rulebook of OEMs and suppliers[23]; and the supplier industry has restructured itself into a tiered form, where first-tier (Tier-I) suppliers occupy the top of the pyramid and deliver OEMs with modules and systems, whose design they are heavily involved in, in a just-in-time (JIT) or just-in-sequence (JIS) fashion. The Tier-I level works with lower tiers (Tier-II, Tier-III…) that supply individual components and smaller modules. This structure is strongly similar to what Womack et al. defined in 1990 for the Japanese automotive industry (Womack et al. p. 146). Yet, the affects of globalisation, cost pressures, innovation-imperative and the urgency to achieve speed economies have transformed the relations the industry to focus on collaborative engineering and production at a global scale

[23] For instance, Porsche AG reportedly benefited from the expertise of lean manufacturing consultants from Japan as it tried to get rid of its financial and quality problems of the early 1990's. Today it enjoys the highest profit margins in the automotive business and recently obtained the majority stake of the VW Group, the world's 4th largest car company (Morgan 1999)

(Mercer 2007 p. 88). Therefore, it can be argued that automotive industry of the 21st is moving beyond Toyotaism into a new chapter.

Suppliers assuming more tasks

It is widely agreed that suppliers carry out an ever greater portion of value creation in automotive industry. The consulting firm Accenture prophesizes that by 2010, three quarters of value creation in the automotive industry will be carried out by suppliers, corresponding to a sizeable increase from the 35/65 supplier / OEM split in 2000 (Krust 2007). FAST2015 and HAWK2015 studies, both contracted by VDA (Association of German Automobile Manufacturers), foresee that the supplier share in value creation will reach 77% and 75% respectively (VDA 2003 pp. 12-16, 2004 p. 19).

A closer look at the details of predictions reveals that in almost all areas OEMs will pass value creation on to suppliers and transform themselves into system-integrators (Fig. 12). Electronic systems are the only exception where OEMs are expected to maintain their share. The necessity to control the rampant complexity in development and final assembly makes a certain degree of R&D and quality assurance effort unavoidable, hence OEMs are, in a way, forced to maintain their level of internal activities in these two areas. On the supplier side, Tier-I level firms are required to gain new capabilities in order to be able to switch to module-based product design and production modes. They have to boost their R&D and logistics competencies, increase their knowledge of their customers' operations, re-align their backward linkages and develop new value creation models (Fourcade/Midler 2005 pp. 150-155).

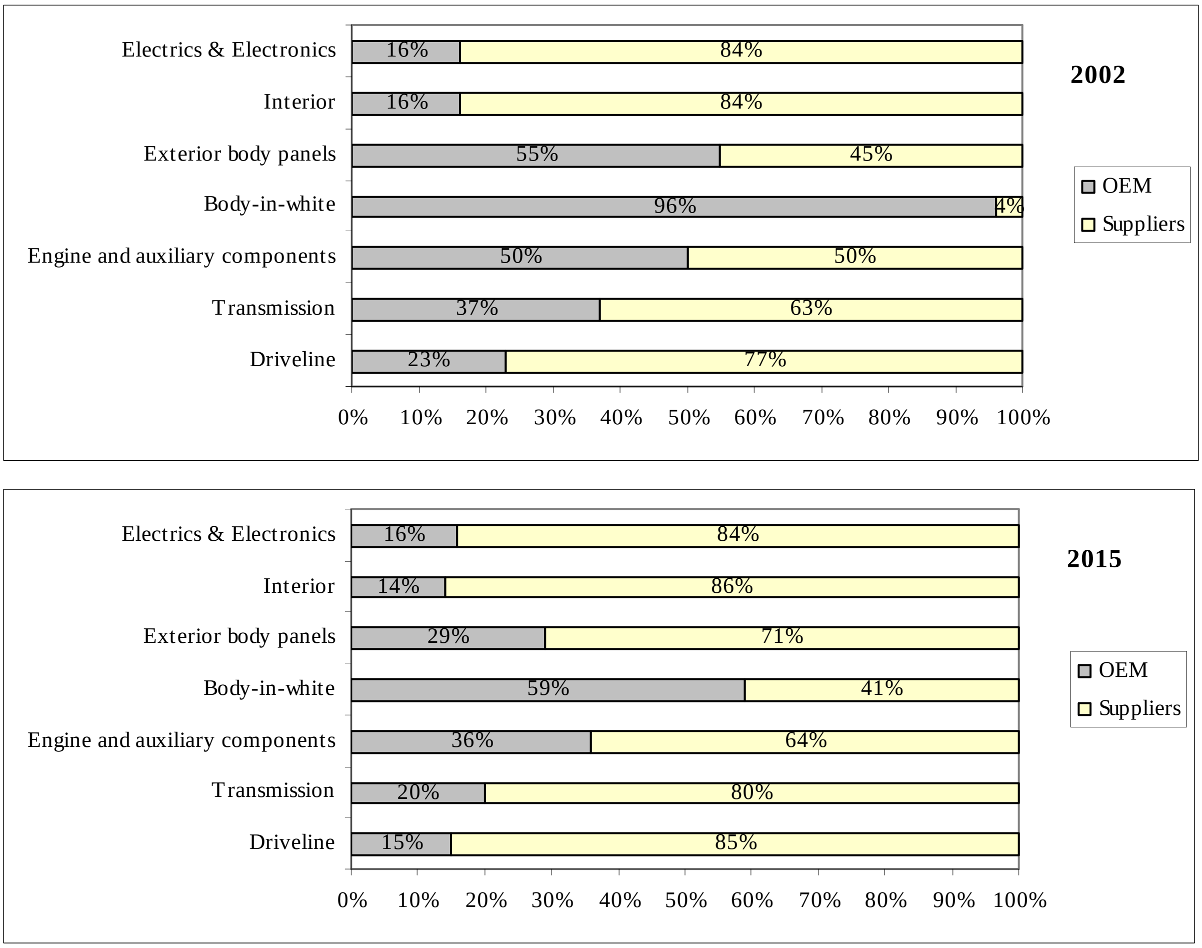

Fig. 12: The growth of value creation between OEMs and suppliers in respective areas

Source: VDA 2004 p. 21

Along with manufacturing and assembly tasks, an increasing amount of service-intensive activities are handed over to outside parties by OEMs. These partly involve low-tech services (e.g. cleaning and catering) and perimeter activities (e.g. IT-back-office tasks and logistics), yet at the same time, complex R&D and development tasks that cover all areas of the vehicle are becoming growth markets (Fig. 13). OEMs turn to development specialists and engineering services firms to overcome cost, time and capacity related challenges. The recently rising demand for cleaner vehicles is an example: OEMs need to access know-how in new driveline concepts (e.g. hybrids) and light weight construction technologies quickly to beat their competition to market. In fact, the rise of these technologies hints at further structural change to come across the value chain for driveline development and component production (Krust/Krogh 2008). The thematic and organisational profiles of these firms are quite diverse, from specialists in single areas such as drive-trains to firms covering the whole spectrum of development and from out-staffing firms to part-hardware producers. The global ranking of development services suppliers displays a striking dominance of firms of German origin, nine out of the top-ten and twenty out of the top twenty-five to be more precise. Of these German firms, some of the bigger names like Bertrandt, MBTech and Bosch Engineering are headquartered in Stuttgart region.

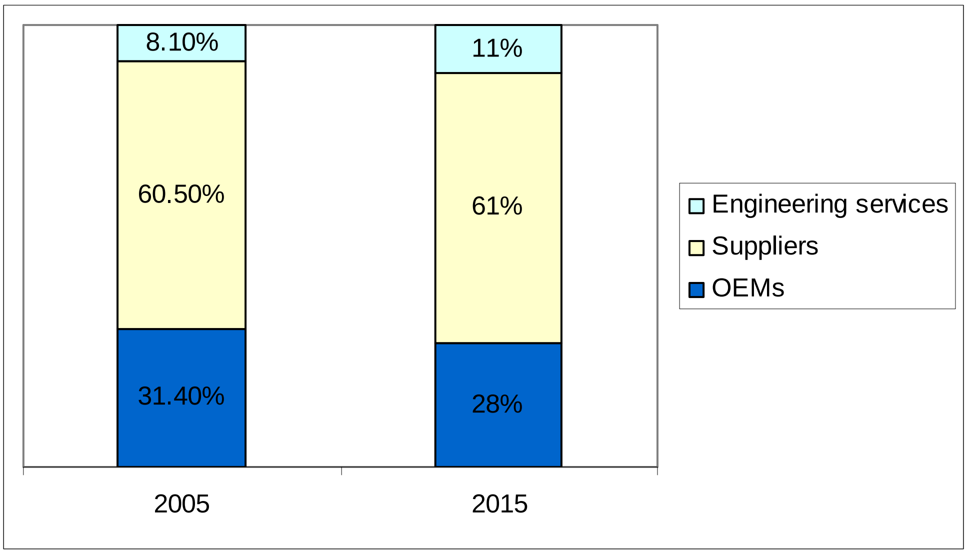

Fig. 13: The forecasted change in respective R&D efforts of OEMs, suppliers and engineering services firms

Source: Oliver Wyman "Car Innovation 2015", summary report 2007 p. 24

The individualization trend in consumer markets reigns in the automotive industry as well. Carmakers are led to offer ever more body-styles, broad ranges of powertrain choices and long lists of optional equipment on products that are increasingly manufactured to order. At the same time, the technological complexity of products rises with each model generation, especially in the so-called premium segments. On the other hand, regulatory pressure forces the industry to develop safer and cleaner products[24, 25]. As product life-cycles are getting shorter with each model generation, the industry is faced with a very challenging business case: to develop more diverse and sophisticated products in shorter periods and to create returns on investment on ever shorter production runs.

Because a large portion of product innovations are sourced by the suppliers, they are quickly diffused among different car makers. Therefore, despite the high number of vehicle variants

[24] For instance, the End-of-Life Vehicle Directive of the European Commission sets new targets for increasing re-use, recycling and other forms of recovery of 'end-of-life vehicles' and components, and phases out certain hazardous substances. About 25% of each end-of-life vehicle currently goes into landfills; the aim is to reduce this to below 5% by 2015.

[25] The most prominent example is the passive safety test program Euro NCAP (European New Car Assessment Program), which is backed by seven European Governments and the European Commission.

and diverse optional equipment, the functionality-based product differentiation across car brands is becoming increasingly smaller. This pushes OEMs to move away from manufacturing and to pay more attention to upholding their branding and brand awareness (VDA 2004 p. 8). Consequently, manufacturers are becoming more involved in downstream activities, which produce higher profit margins on smaller capital investments, to bolster their brand images and to maintain closer relationships with their customers (e.g. taking larger stakes at retail channels and setting-up own financing institutions[26]).

To summarize, with its strong backward and forward linkages, automotive continues to be as crucial and dynamic an industry as it has ever been. It is literally a mirror in which most economic and business trends can be reflected: globalization, structural change, geographical shifts, tertiarisation, outsourcing, shifting markets and value creation, electronics, software, climate change and innovation-pressures. In this sense, the functioning of the automotive industry can provide eventual hints to understanding today’s economy.

The role of electronics and software in motor vehicles

Electrics and electronics systems (EE) are singled out by many experts as the most important source of product innovation in the automotive industry[27]. These systems are used in all areas of a vehicle, i.e. interior, chassis and driveline, and they provide benefits in terms of comfort, lower fuel consumption and safety, among others. Due to the central role of suppliers, EE innovations diffuse across different market segments and manufacturers in relatively short periods. Car makers often share the cost for the development of new systems with suppliers and after a customary period of exclusivity, which ranges from 6 to 12 months, suppliers are allowed to sell these to other OEMs (Borgmann 2007). The importance of electronic systems for OEMs is indirectly evident in the performances differences between suppliers of EE and other vehicle systems (Table 2). Suppliers for comparatively simpler commodity products, like ThyssenKrupp Automotive (e.g. metal components) and Faurecia (largely seats, interiors and exhaust systems), produce considerably lower margins than high-technology systems suppliers such as Bosch, Autoliv and Siemens VDO. The innovative nature of their products allows the latter group to have a stronger price-position against the OEMs, which is most visible in the performance-differential between tire-makers Michelin and Continental. The

[26] An example is Mercedes-Benz Bank of Daimler Group, which is not only an institution for financing vehicle sales, but also has a fully fledged bank since 2002 (Grammel, & Seibold 2004 p. 27).

[27] Thomas Weber (Board Member of Daimler, responsible for Research & Development Mercedes-Benz Cars) expresses a common sentiment in the industry when he comments: “In the future 90% of all innovations on a motor vehicle will result from electronic systems” (Kruse 2007).

former concentrates largely on tire-manufacturing and despite being the global market leader, it delivers a profit margin of 0.9%. However, Continental, which has decidedly diversified into electronics and chassis systems, manages a significantly higher margin of 4.1%.

Table 2: The largest 15 European-owned automotive suppliers by profit-margin, 2006

	Supplier	Profit margin (%)
1	Autoliv	8.3
2	Bosch	6.7
3	Siemens VDO Automotive	6.6
4	GKN	4.2
5	Continental	4.1
6	Magnetti Marelli	4.0
7	Mahle	3.5
8	Valeo/ZF Friedrichshafen/Behr (tie)	3.1
9	Hella	3.0
10	Banteler	2.6
11	Faurecia	2.4
12	Michelin	0.9
13	ThyssenKrupp Automotive	0.6

Source: Automotive News Europe (Lewin 2006)

4.2. Structural change in the Stuttgart region

Geographically, Stuttgart region covers the city of Stuttgart and its five neighbouring counties, namely Böblingen, Esslingen, Göppingen, Ludwigsburg and Rems-Murr (Fig. 14). Although it is composed of NUTS3 regions and is often called a metropolitan region, Stuttgart does not correspond to a NUTS2 level area[28]. Instead, it is one of the 12 regions in the state of Baden-Württemberg (BW) that were defined and formed as administrative entities in 1973 after a dedicated state law. Initially called "Mittlerer Neckar" (Middle Neckar), it was re-named in 1992 as Stuttgart Region[29]. The organizational centre of this institutional constellation is "Stuttgart Regional Association (Verband Region Stuttgart - VRS)", which

[28] The administrative district Stuttgart ("Regierungsbezirk Stuttgart"), which is one of four such districts in Baden-Württemberg, corresponds to the NUTS2 level and covers Stuttgart Region, Heilbronn, Tübingen, Schwäbisch-Hall, Pforzheim, Reutlingen and their respective counties. This mezzanine governance level links local authorities to state level administrative units.

[29] For the rest of the study Stuttgart Region will be referred to as Stuttgart, unless noted otherwise.

acts as the joint representation organ for municipalities[30]. The population of the region is around 2.7 million on an area of 3700 km^2 spread over 179 municipalities. It is an assembly of six separate sub-units with remarkably similar population and economic activity levels, an in that it differs from the more common centre-heavy metropolitan structures such as Munich (Gaebe 2004 p. 220).

Fig. 14: Map of Stuttgart region

Source: Verband Region Stuttgart

Table 3: Stuttgart region in Baden-Württemberg

	Stuttgart region	Baden-Württemberg	Stuttgart in BW (%)
Surface area (km^2)	3.654	35.752	10.20%
Population (2006)	2.668.833	10.738.753	24.90%
GVA (€ mio.) (2005)	92.115	325.893	28.30%

Source: IHK Region Stuttgart 2007b

Before other important BW-regions like Karlsruhe, Mannheim, Heidelberg and Freiburg, Stuttgart is the social and economical centre of the prosperous BW state with which it shares common structural characteristics (Fuchs/Wolf 1999 p. 299). The presence of the state parliament, ministries and other government units turns the state capital City of Stuttgart into an important political and institutional node. While occupying about only 10% of its surface area, Stuttgart region accommodates 25% of the BW population and produces 28 % of BW

[30] VRS is responsible for regional planning, transport infrastructure (e.g. it manages the inter-urban railway service [S-Bahn], and also carries out locational business promotion and regional economic development support.

GVA (Table 3). Both Stuttgart region and BW outmatch national averages in basic economic indicators and Stuttgart fares quite well when compared to leading German metropolitan regions.

Table 4: Metropolitan regions in Germany in sectoral comparison, 2005

	GVA per employee[31], industrial sector (2005, €)	GVA per employee, service sector (2005, €)	
Hamburg	69.914	68.105	Munich
Munich	68.348	63.631	Hamburg
Köln/Bonn	67.870	60.272	Rhein/Main
Stuttgart	66.794	53.742	Stuttgart
Rhein/Main	64.992	51.327	Köln/Bonn
Baden-Württemberg	62.793	51.104	Baden-Württemberg
Germany	59.055	50.463	Germany
Berlin	54.260	44.043	Berlin
Leipzig/Halle	52.144	40.556	Leipzig/Halle
Dresden	51.647	40.223	Dresden

Source: IMU/IAW 2007

Despite Stuttgart's third place in terms of GVA per capita among metropolitan regions (Table 4), there is a wide gap to the first in the list, Munich. One explanation here is Munich's higher commuter numbers (IMU/IAW 2007 p. 38), yet the difference in services sector output suggests an additional explanation. Even though ranked 4th in terms of the industrial and services sectors, the gap between Stuttgart region and the top of the list is more than three times higher for services. It appears that Stuttgart region has not been able to come up with an answer to the sophisticated services branches in Munich (enterprise services, especially in finance and "new-economy"), Hamburg (media and creative sectors) and Frankfurt am Main (finance and others).

In contrast to many European regions, manufacturing continues to be a vital economic activity for Stuttgart and it leads EU-25 metropolitan regions in terms of secondary sector employment (Eurostat 2007 p. 10, Werner and Fischer 2005 p. 10). In 2005, manufacturing produced 39.4% of regional value creation and 34.0% of employment (Germany: 29.3% and 25.9%, respectively). The competitiveness of the manufacturing sector is evident in its export

[31] In comparison to "wage-employee", which was previously defined, "employee" refers to the term "Erwerbstätig", which covers all persons that have a gainful employment, including the self-employed.

quota[32] which at 55.3% is far higher than the national average (40.6%) and only second to Munich (58.1%). This success is due to the three leading industrial sectors automotive, machinery and electronics/electrical engineering, which created about 48% percent of industrial employment and 81% of the industrial turnover in the region in 2006[33]. Fig. 15 presents the growing role of transport equipment sector, which is largely formed of automotive, in manufacturing sector turnover. Moreover, about 92% of industrial exports were sourced by these three industries, with the notable role of automotive at 63.7%.

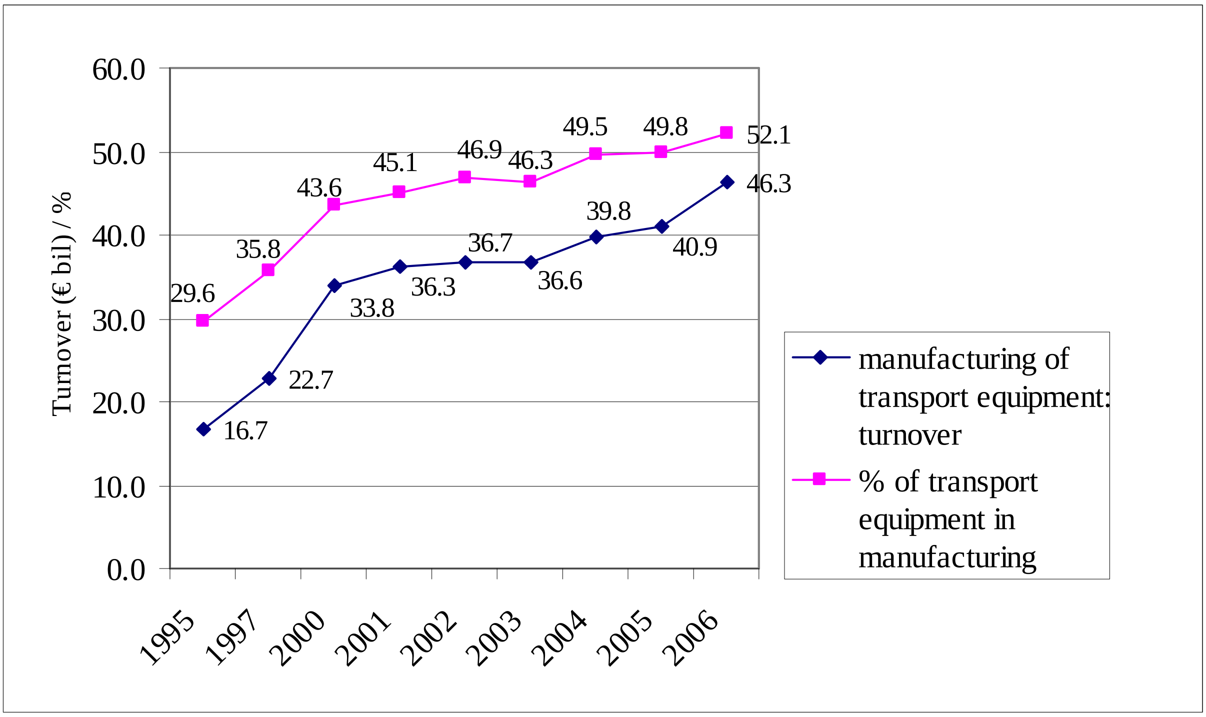

Fig. 15: The development of transport equipment industry turnover in Stuttgart region in absolute figures and as a percentage of the overall industrial sector, 1995-2006

Source: IMU/IAW 2005, 2007 and own calculations

According to a Eurostat report[34] based on data from 2004, Stuttgart region is runner up to Lombardy in absolute employment numbers in the high-tech and medium tech sectors, to which automotive and machinery industries belong. In relative terms, Stuttgart has the highest ratio of high- and medium-high-tech sector employment among EU-25/EFTA regions (Eurostat 2006 p. 4). Another Eurostat report based on data from 2006 and which only

[32] Export quota is the proportion of export income to overall results of an industry.

[33] For enterprises with 20 or more employees. Source: IHK Region Stuttgart 2007a.

[34] In this report, as in most EU publications, the geographical borders of Stuttgart Region are taken as that of the larger NUTSII level metropolitan area. However, the economic characteristics and sectoral compositions of these adjacent regions display similarities, for instance with strong presences of automotive and machinery industries.

considers high-tech sectors[35] places Stuttgart in the 16th place among EU-27 NUTS II regions (Eurostat 2007 p. 1).

Nevertheless, manufacturing employment in the region has been steadily receding since the end of the 1990s and – during the same time period – the enterprise services sector has been increasing its share. Between 1999 and 2006 the former slimmed down by 9.3% (36.344 wage-employees) while the latter gained 29.8% (32.500) (IMU/IAW 2007 p. 20 and 24). Furthermore, at 74.1%, functional tertiarisation ratio based on employee-tasks in Stuttgart comfortably surpasses the level sectoral tertiarisation 59.4% (ibid. p. 18). This process of structural change corresponds to that of BW, where services employment continues to grow since it overtook the manufacturing sector in the early 1980s (Vullhorst/Winkelmann 2007 p. 11). While commodity components are shifted to lower-cost locations, especially to new EU member states, regional operations focus on more complicated manufacturing and assembly tasks and knowledge-intensive services such as design, R&D and management.

In terms of investments in R&D and patent production, Stuttgart region comfortably surpasses other metropolitan regions. In 2003, the R&D investments of private firms reached 5.2% of the regional GDP, ahead of runner-up Munich (4%) and 2.5 times of the national average. In absolute terms, these investments reached nearly 4.8€b and thereof, the automotive industry was by far the highest spender with 72%, followed by electrical/optical equipment and machinery with 15.4% and 8.7% (Statistisches Landesamt Baden-Württemberg 2006 p. 58). The same order was also to be seen for dedicated R&D employment: 66.7%, 17.3% and 11.1%, respectively. In comparison, the statistical group "real-estate, renting and business activities", which contains knowledge intensive business services branches, accounted for 1% and 1.4% of regional R&D investment and employment respectively[36]. Stuttgart's position as the centre of knowledge-production in BW is evident in the fact that the region employs approx. half of the R&D staff in BW (Egetemeyr/Werner 2008 p. 23). As in R&D investments and employment, Stuttgart also leads the German metropolitan regions in terms

[35] High-tech sectors comprise high-tech manufacturing (NACE Rev 1.1: 30 Manufacture of office machinery and computers; 32 Manufacture of radio, television and communication equipment and apparatus; 33 Manufacture of medical, precision and optical instruments, watches and clocks) and high-tech knowledge-intensive services (NACE Rev 1.1: 64 Post and telecommunications; 72 Computer and related activities; 73 Research and development).

[36] This low figure is partly due to the method of measurement, which disregards efforts taking place outside a dedicated R&D department.

of patent intensity with 3312 patents issued per million employees. Munich and Dresden trail behind with 2493 and 1361, respectively (IMU/IAW 2007 p. 42).

In his account on Stuttgart region, Gaebe makes several remarks regarding the structural change process in the region. He acknowledges diseconomies of agglomeration effects in high costs of land and labour and scarcity of suitable land. The region also has a relatively unfavourable "connectedness" by transport, which is augmented by increasing congestion (Gaebe 2004 p. 220). However, recent developments and discussions, for instance the approval of the investment plan for the Stuttgart 21 project[37], newly opened trade-fair grounds, discussions for a second runway to Stuttgart / Echterdingen airport, are signs of efforts to improve the connectedness of Stuttgart and to support the service sectors in the region.

As mentioned before, Stuttgart region shares significant representative characteristics with BW (Fuchs/Wassermann 2005 p. 231). Indeed, Schmitz goes as far as to state that "most of the discussion of the "model BW" [in industrial districts literature] is essentially about [Stuttgart region]" (Schmitz 1992 p. 91). In this sense, it is permitted to consider observations on BW as indicators for developments in Stuttgart region. During the deep crisis of the early 1990s, regional policy makers correctly identified that the problems were far from temporary or cyclical. In order to devise means to tackle the structural crisis, a report was commissioned to a working group formed of high-level industry managers, academics and trade union representatives. This group, "Future Commission 2000", found that the region had failed to adapt to the transformation of world economy and that a far-reaching regional structural change was due (Zukunftskommission Wirtschaft 2000 1992 p. 10).

As a solution, the report advised a dual strategy of bolstering the competitiveness of existing industries (meaning actions to support the leading trio of manufacturing industries) and pushing to "catch-up" with United States and Japan in new technologies. The Commission also urged private enterprises to reform their organizational structures and to devise new supply and sales strategies for the new world order of globalization. Their recommendations were not about fighting liberalization or protectionism. On the contrary, they preached utilising locational advantages and opportunities. For instance, retaining high value-added tasks at home and shifting simpler production tasks to low-cost locations is an explicit

[37] Stuttgart 21 is a large-scale construction project that aims to transform a portion of the city centre of Stuttgart by introducing a new main train station, office and residential spaces. The new station will improve the rail-connectivity of the region by completely reorganising the alignment of tracks and routes.

suggestion (ibid. p. 12). As for the catch-up strategy, the authors of the report invited policy makers to invest in infrastructure and pre-selected new technology projects and to moderate the intra-regional dialogue actively. During the following years, significant investments took place at regional and state levels e.g. an “Innovation Council”, regional and state development agencies, new technical faculties, biotechnology parks and more were set up (Heidenreich/Krauss 1998 pp. 242-243, Strambach 2002 p. 226). As stated before, regional enterprises embraced the geographical division of labour along the lines of the Commission’s suggestions, and today even the relatively smaller enterprises have links to low-cost locations, especially in central and east Europe. Certain public initiatives, Baden-Württemberg International among them, have worked to connect BW firms with global markets and continue to do so today.

Following the Future Commission’s report, a regional economic development agency (WRS) was established for Stuttgart in 1995. It was conceptualized as an operational offshoot to Verband Region Stuttgart. WRS adopted Porter’s cluster concept as a template and set the support of automobile cluster among its priorities. During the years, the organization has grown and added new areas of focus, which today include media, film and other creative industries as well as innovation and investor support services.

To sum up, Stuttgart region has shown sizeable success in untangling its functional, cognitive and political lock-ins and transforming itself in many dimensions (Fuchs/Wassermann 2005 pp. 244-245). However, it is still dependent on too few sectors, especially on automotive, and despite the increasing employment in enterprise services, the knowledge-intensive services sector is yet to reach the level of supra-regional competitiveness of manufacturing. The weaknesses pointed at by Hahn in 1990 – dependence on automotive and other relatively slow-growth industries, competition from low cost and developing countries, and relatively under-representation of high-growth new sectors – are still relevant to a certain degree today (Hahn 1990 p. 217). A noticeable degree of conservatism still reigns in the political and business realms and challenges regarding new ways of knowledge-production and sharing remain as gatekeepers for a further reaching transformation of Stuttgart region (Gaebe 2004 p. 223).

4.3. Stuttgart automotive cluster

The German automotive industry has three quarter million employees and each seventh job in Germany is directly or indirectly linked to it. Although it is soon likely to lose its third place in terms of production units to China (after United States and Japan), Germany appears set to retain its leadership in automotive exports in terms of value. Brands owned by German vehicle manufacturers Daimler AG[38], BMW Group and VW Group dominate the premium end of global markets and German firms have also strengthened their position at the top of the supplier market.

Stuttgart region is literally the birthplace of automobile and it was home to some of the most important early innovators of the industry such as Gottlieb Daimler, Robert Bosch and Wilhelm Maybach. Today, it is endowed with an exemplary and competitive automotive cluster. To begin with, it is the historical home of two of the world's most renowned and successful OEMs: Daimler and Porsche AG[39]. Daimler group, to which the Mercedes-Benz (MB), Smart, Maybach, EvoBus and Daimler Trucks brands belong, has its respective headquarters for passenger and commercial vehicles and three main plants for passenger vehicle production in the region (Untertürkheim: engines, axles, transmissions and other components; Bad-Cannstatt: engine assembly; Sindelfingen: C-/E-/S/CL/CLS-class models and Maybach, 408.000 units in 2005). The R&D activities for passenger vehicles are predominantly carried out in "Mercedes-Benz Technology Center" in Sindelfingen, which will be expanded till 2010 with additional functions transferred from other national locations. The 7300 employees in MTC undertake R&D, design tasks for the car-group and double as a pre-development location for other automotive divisions of Daimler. The central R&D operations of commercial vehicles are also located in Untertürkheim.

The Porsche premises in Stuttgart-Zuffenhausen, which were opened in 1950 still host the main factory where all 911-models (38.959 units in 2006/07) and engines for all three production locations are assembled[40]. Indeed, Porsche is currently expanding its facilities (larger painting and design facilities among others) and will be opening its corporate museum next to the factory in 2008. The main R&D centre is in Weissach, where the subsidiary Porsche Engineering Services, which offers services to other carmakers as well, is also located. Porsche Consulting (process and enterprise consulting) and MHP (process and IT consulting) are also located within Stuttgart region.

[38] Hereafter referred to as Daimler.

[39] Hereafter referred to as Porsche.

[40] Porsche assembles the Cayenne model in Leipzig in its own premises and the assembly of Boxster/Cayman model line is to be transferred to Magna Steyr operations in Graz, Austria from the current contract-manufacturer Valmet Automotive of Finland.

In the immediate vicinity of Stuttgart region, in Neckarsulm, Audi AG[41] has a major manufacturing site (e.g. manufacturing of several versions of the large-selling model A6, exclusive manufacturing of the aluminium bodied flagship model A8 and the assembly of the body-in-white modules of Lamborghini Gallardo), the main facilities of Quattro GmbH (internal division for the upper-segment performance models), an engine development centre that also serves VW Group and the aluminium / light-construction research centre of the VW Group. Although its links to Stuttgart region are perceptively weaker than to Bavaria where the main corporate operations are located, Audi-Neckarsulm does entertain close links with the region’s suppliers.

Robert Bosch GmbH[42], the world’s largest automotive supplier in terms of sales, is at the top of a diversified regional supplier base that includes Mahle (engine components and peripherals), Behr (air conditioning and engine cooling systems), Dürr (painting systems and facilities), Eberspächer (exhaust technology and heaters), Recaro (seats), Mann+Hummel (filter and air intake systems) and Beru (diesel cold start systems). These globally operating firms have their headquarters, R&D facilities and manufacturing operations in the region. An interesting feature of these firms is the degree of their openness to globalization, which is best exemplified by Bosch. Although it was an internationalized firm even before “globalization” became a buzz-word, Bosch’s level of engagement in overseas activity is exemplary. It is present in 50 countries and in all significant automotive locations. For instance, Bosch enlists in the expansion of the automotive industry in developing countries and takes an active part in the growing “very affordable vehicle” trend. Together with Stuttgart-headquartered Mahle and Behr, Bosch played a significant role in the development of the recently launched Tata Nano, allegedly the cheapest car in the world at approximately 1700 € before taxes. Bosch operations in Germany and India cooperated on the development of dedicated low-cost modules such as brake and injection systems and eventually these systems will be manufactured by Bosch plants in India (Lamparter 2008).

An interesting insight into the automotive industry in BW and Stuttgart region is provided by a Prognos Study on export and import values (Prognos 2007). Between 2001 and 2005, the exports of vehicles and parts from BW increased by 19% and 38%, respectively. While this is a clear sign of competitiveness and of globalization for the regions’ suppliers, the 79% jump in imported vehicle parts within the same period is the more telling fact (ibid. p. 72).

[41] Hereafter referred to as Audi.

[42] Hereafter referred to as Bosch.

Stuttgart's automotive cluster is increasingly using the cost advantages available elsewhere to remain competitive, especially for the production of components. At the same time, the automotive operations in the region are concentrating on more sophisticated services, manufacturing and assembly tasks, which is generally a situation as described in the Bazaar Economy thesis of Sinn (2006 p. 1161).

A group of foreign-owned firms (TRW, Valeo and Faurecia, among others) and a large number of local Tier-II and Tier-III level suppliers complete the manufacturing-oriented suppliers group in the region (a sample of regional suppliers is presented in Fig. 16). Numerous engineering firms with varying degrees of automotive focus are active and crucial members of Stuttgart's cluster. The breadth of services these firms deliver varies greatly, from tool design to complete system development capabilities that include everything from pre-development to production. These firms operate at different levels of "globalization". While household names like Bertrandt, Porsche Engineering Services and MB-Tech do operate globally; smaller engineering offices tend to concentrate strongly on regional customers.

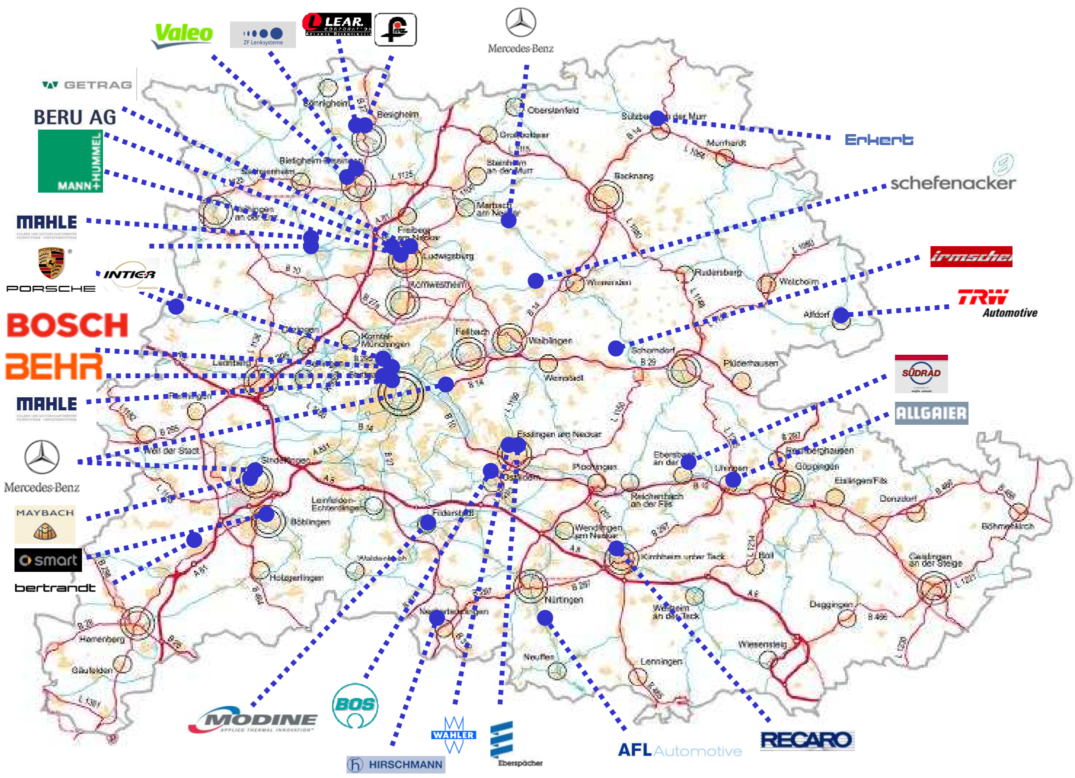

Fig. 16: An indicative sample of the larger automotive firms in Stuttgart region

Source: WRS and own representation

Due to reasons discussed in Section 3.2, standard statistical records and Business Register data provide different results on the automotive industry. The former lists 99 firms as of 2006 in the statistical group "Manufacture of transport equipment"[43], while Business Register reports 222 active enterprises and a total employment of 134.691 persons in "Manufacture of motor vehicles, trailers and semi-trailers." According to EU definitions, most of these 222 firms are so called "micro-enterprises" with up to 10 employees and SMEs[44] (Table 7). The bulk of automotive employment (96%) is created by large enterprises, which only amount to 16% of all firms (Table 5). Similar evidence is also available from a list of the biggest employers in the region published by the regional Chamber of Commerce, which reveals that OEMs Daimler (71.729 employees), Porsche (9.478), and Bosch (24.478)[45] occupy the top three places. The "smaller" suppliers of the region such as Behr (4.643), Mahle (3.700), TRW (2.000), Mann+Hummel (1.600), Valeo (1.350), Allgaier (1.317) and Eberspächer (1.060) are among the most significant regional employers (IHK Region Stuttgart 2007a).

Table 5: Total number of firms and employees in the automotive sector in Stuttgart region as of December 2006

	Total	Firm size in terms of no. employees		
		0 - 9	10 - 249	250 <
Manufacture of motor vehicles, trailers and semi-trailers (WZ/NACE 34)				
No. firms	222	107	79	36
No. employees	134.691	194	5.447	129.05
Private enterprises (WZ/NACE 10 – 74, 80 – 93)				
No. firms	125.675	106.733	11.609	458
No. employees	954.709	140.72	421.534	392.455

Source: Business Register, German Federal Statistics Office and own calculations

Employment in the automotive sector has taken different developments paths for OEMs and suppliers. After successive years of growth between 1999 and 2004, OEM numbers have decreased since then, largely due to the closing of Neoplan's operations and to Daimler's restructuring measures. Suppliers have been hovering around the 17.000 mark till 2006 when a large jump to over 21.000 occurred. However, this is the result of a reallocation of numbers

43 „Manufacture of transport equipment" includes additional activities to automobile industry, e.g. building of trains, which are statistically not significant as their employment share amounts to 0.7% within transport equipment (IMU & IAW 2007 p. 7).

44 The SME definition of EU covers enterprises with up to 250 employees and an annual turnover of € 50 mio or an annual balance -sheet total of €43 mio.

45 Includes those employed in activities outside the automotive sector.

within statistical tables[46]. Therefore, supplier employment has actually decreased by 32 persons in real terms. Considering the continuously increasing turnover values of the regional industry (Table 6), it is evident that the productivity in the regions has been on the rise.

Table 6: Development of employment in the automotive industry in Stuttgart region, 1999-2006

	1999	2004	2005	2006	‘99/’06	%	‘04/’06	%
Manufacture of motor vehicles	80.606	91.297	89.157	84.883	4.277	5.3%	-6.414	-7.2%
Manufacture of parts and accessories	17.157	16.974	16.57	21.538	4.381	25.5%	4.564	27.5%
Manufacture of bodies, trailers and semi-trailers	1.406	1.657	1.209	895	-511	-36.3%	-762	-63.0%
Total	99.169	111.932	106.936	107.316	8.147	8.2%	-4.616	-4.3%

Source: IMU/IAW 2005, 2007 and own calculations

The functional tertiarisation mentioned before applies to the automotive industry located in the rest of BW and Germany as well (Table 7). However, the change is more rapid in Stuttgart region and at 52.3% overall functional tertiarisation is one fifth higher than the national average. The emphasis on technical tasks including R&D activities in the Stuttgart cluster is also striking. Despite the continuing role of manufacturing, in fact services are at least as important for the automotive cluster. The relatively lower degree of social division of labour in services tasks can be partly explained by complexity due to the sophistication of products and processes involved. Both OEMs and suppliers are targeting upper, technologically sophisticated ends of the automotive markets. It could be claimed that the perceived and real costs and risks involved in the management of the necessary knowledge-intensive processes limit the sharing of these tasks across firm boundaries.

[46] Namely, 5000 jobs at Bosch were shifted from electrics/electronics to automotive sector (IMU & IAW 2007 p. 93).

Table 7: Transport equipment employees according to the functional profile of their tasks (G: Germany, BW: Baden-Württemberg, SR: Stuttgart region), 1999-2006

	2006 (%)			+/- ‘99/’06		
Automotive industry	G	BW	SR	G	BW	SR
Production tasks	55.4	51.9	45.7	-2.6	-5.6	-9.6
direct	26.6	24.2	21.5	-8.6	-12.4	-10.1
indirect	25.5	25.1	20.8	6.9	6.4	-5.0
Services tasks	42.3	46.0	52.3	16.9	19.2	28.1
Technical	17.3	19.9	24.8	24.7	27.1	37.7
Management	12.8	13.8	14.8	22.3	21.,8	25.,0
Logistics	8.3	7.3	6.0	-0.4	0.,1	1.0
Commercial	1.6	1.5	1.8	16.7	20.0	52.7

Source: IMU/IAW 2007 p. 96

Related evidence regarding the increasing size of services tasks is available in the rise in numbers of employees carrying out directly IT-oriented tasks in automotive firms (Table 8). While these jobs display a stable level for the machinery industry, automotive firms steadily bolster their staff in this department. The general trends in the sector and the region (e.g. lean manufacturing methods, rising sophistication of products and increasing geographical spread of supply chains) are likely reasons for the growing role of IT and software applications for automotive industry.

Table 8: Total number of employees with IT-occupations in automotive and machinery sectors in Stuttgart region, 1999-2007

	Manufacturing of motor vehicles, trailers and semi-trailers (ZW2003 34)	Change 1999=100	Manufacturing of machinery and equipment (ZW2003 29)	Change 1999=100
1999	1.347	100	1.091	100
2000	1.439	107	1.070	98
2001	1.549	115	1.080	99
2002	1.614	120	1.120	103
2003	1.699	126	1.144	105
2004	1.744	129	1.127	103
2005	1.761	131	1.139	104
2006	1.788	133	1.130	104
2007	1.807	134	1.120	103

Source: Federal Employment Office and own calculations

Stuttgart is also endowed with a rare sophistication in terms of automotive relevant academic and research institutions: various institutes at the University of Stuttgart (e.g. on metal forming technology, micro-electronics, materials, traffic control and paint materials), the vehicle technology faculty at the Esslingen University of Applied Sciences and numerous other institutes and organizations (e.g. Fraunhofer Institute for Manufacturing Engineering and Automation, Max-Planck Institute for Metals Research and Institute for Metal-forming at University of Stuttgart). The Institute of Vehicle Concepts at the DLR (German Aerospace Centre) undertakes future-oriented research on vehicle and transport concepts. New materials and fuels are investigated. There is also a tradition of collaborative projects in the form of contract research between the automotive industry and the above-mentioned academic institutions, which is supported by the availability of public funds from regional, state and national levels.

The most dedicated research institute in the cluster is a twin organization between the Institute of Combustion Engines and Automotive Engineering (in German IVK, active in basic research) and the Research Institute of Automotive Engineering and Vehicle Engines (in German FKFS, active in applied research), which have a long history of automotive related research dating back to the 1930's. These twin institutes have organic links and they share infrastructure and personnel (e.g. PhD students doubling as research engineers in projects).

Both organisations have three main areas of activity: engine technology, vehicle electronics and vehicle development. They have access to excellent facilities at the University of Stuttgart: not only the High Performance Computing Centre Stuttgart[47] (one of best of its kind in Europe) for vehicle simulation tasks, but also a wind tunnel[48].

FKFS entertains close relations with industry and plays a central role in three recent cooperation initiatives addressing crucial trends in the automotive sector. The first one is the "Automotive Simulation Centre Stuttgart" that brings together OEMs and suppliers (Daimler, Porsche, Adam Opel AG and Karmann), hardware and software firms (Cray, INTES, Altair, DYNAmore among others), University of Stuttgart and VDC Fellbach, which is a regional competence centre that is specialized in virtual reality technology. The alliance aims to stimulate application-oriented, pre-competitive research in numerical simulation by utilizing the capacity at the High Performance Computing Centre of University of Stuttgart. The second engagement of FKFS, a joint research centre for vehicle simulation software with software firm EXA Corporation, is thematically related to the first one and aims to draw the physical and virtual development process closer to each other. The third initiative where FKFS takes on a coordinating role is the "Automotive Electronics Innovation Alliance", which is financed partly by the Federal Ministry of Education and Research. The alliance partners include Audi, Bosch, BMW, Continental, Daimler, Elmos and Infineon, who aim to undertake pre-competitive research in hardware-related issues in automotive electronics and to explore options for hardware standardisation across OEMs and product segments (Reuss 2008). These initiatives are indeed motivated by domineering industrial challenges but the fact that they have been called to life in Stuttgart also has to do with the connectedness of FKFS and the legacy of cooperation in the region.

As mentioned in the previous section, Stuttgart region leads Germany in terms of R&D investments and automotive sector dominates the ranks in terms of yearly average patent registrations. A very comprehensive study by Altvater-Mackensen et al. provides a glimpse at the details of patent production and scientific publications in seven German regions including Stuttgart, for a timeline between 1995 and 2000 (2005 pp. 515-22). In terms of patent subject, automotive occupies nine out of ten places, with "dynamo-electric machines" as the sole exception (Table 9). As for assignees, Festo (manufacturer of machinery and related systems), Alcatel (electrics and electronics) and Alfred Kärcher (manufacturer of cleaning systems and

[47] The High Performance Computing Centre also works in close cooperation with Porsche AG for simulation related applications.

[48] This wind tunnel is one of two test-locations for global product development at General Motors.

equipment) join an automotive-filled list (Table 10). The role of Bosch is also evident in the first table, as the patent areas (e.g. combustion engines and brake control systems) correspond to those of Bosch activities. The presence of extensive and competitive automotive supplier networks is evidently a distinguishing factor in terms of knowledge-production. In comparison, in Munich, another metropolitan area that hosts a prominent OEM and its R&D operations, electrics and electronics dominate patent production.

Table 9: Average number of patents ranked by IPC-Classes in Stuttgart region, 1995 - 2002

Rank	No. patents	IPC-Class[49]/Explanation
1	125	F02M/Supplying combustion engines in general
2	102	B60R/Vehicles, vehicle fittings or vehicle parts
3	70	F02D/Controlling combustion engines
4	46	B60T/Vehicles brake control systems or parts thereof
5	40	B01D/Separation
6	38	B60S/Servicing, cleaning, repairing, supporting, lifting or manoeuvring of vehicles
7	33	B60K/Arrangement or mounting of propulsion units or of transmissions in vehicles
8	14	B62D/Motor vehicles, trailers
9	13	H02K/Dynamo-electric machines
10	12	F16D/Couplings for transmitting rotation, clutches, brakes

Source: Altvater-Mackensen et al. 2005 p. 520

[49] IPC: International Patent Classification

Table 10: Average number of patents ranked by assignee in Stuttgart region, 1995 - 2002

Rank	No. patents	Patent assignee
1	966	Robert Bosch GmbH
2	286	Daimler-Chrysler AG
3	64	Porsche AG
4	53	Filterwerk Mann+Hummel GmbH
5	49	TRW occupant restraint systems GmbH & Co KG
6	26	Festo AG & Co.
7	13	Behr GmbH & Co.
8	11	Mahle Filtersysteme GmbH
9	9	Alcatel
10	9	Alfred Karcher GmbH & Co.

Source: Altvater-Mackensen et al. 2005 p. 520

Looking at the statements in the afore-mentioned Future Commission report, one can infer that during the period up to the early 1990s crisis, Stuttgart region had developed into a location of “proximity without interaction”, where the local buzz was weak and cognitive and relational lock-ins developed (Zukunftskommission Wirtschaft 2000 1992 p. 17, Bathelt et al. 2004, Grabher 1993, Section 2.1.3). The creation of the regional development agency, WRS, was partly aimed at solving this problem. For WRS, the stimulation of new forms of vertical and horizontal communication and cooperation in the region has been a priority. There are other facilitators of communication and cooperation in the region as well. The regional chamber of commerce is highly active in its services (e.g. dedicated reports and studies on regional economy, cooperation with educational institutes and training programs) and is an important point of contact especially for smaller enterprises. Moreover, Stuttgart is the node for numerous substantial public and private organizations that operate at the BW level, among them BW-International and MFG-BW[50]. These organizations do not necessarily address the automotive industry exclusively, but a lot of what they do touches the automotive cluster in some form. All things considered, Stuttgart region is not short of actors that facilitate inter- and intra-regional interaction.

Considering the characteristics presented above, the automotive industry in Stuttgart region qualifies as a fully fledged cluster. Upstream and downstream elements of the automotive

[50] BW-International is a public agency that aims to support firms from the state of BW to enter foreign markets and to attract foreign investments. MFG Medien- und Filmgesellschaft is also a public initiative that aims to support IT and media-related industries in BW.

supply chain (e.g. sophisticated OEMs and components suppliers, specialized services firms and production-machinery producers), relevant research and academic institutions, financial services and other related sectors are all present. In addition, complementary members of a cluster such as trade associations, cluster and other cooperation facilitators are exemplary in their presence.

German car manufacturers and suppliers have gone through a transformation since the dramatic structural crisis of the early 1990s (Jürgens 2004 pp. 415-416). Stuttgart region experienced the same fate and it appears to have succeeded in breaking the grow-peak-decline process of clusters (Morgan 1999 p. 75). Despite this, the practical challenges for the regional automotive industry have changed much less than one would expect. In 1992, Böhm et al. (pp. 175-180) reported the following trends and issues for the automotive industry in "Stuttgart area": outsourcing of development tasks to suppliers, increasing awareness for environment, cost-pressures, decreasing number of direct suppliers to OEMs, consolidation, "internationalization" (read globalization) as a threat to jobs in the region as firms move tasks to *South*-European countries. On this background, Böhm et al. recommend a long-term strategy based on a closer integration of development, assembly and quality, which is not far from what the Future Commission 2010 report advocated a year later. The change the cluster has gone through since appears to be along these recommendations. The onus is now on more sophisticated products, processes and services, while low-end production functions are sourced from outside the cluster's immediate spatial borders. However, despite the success in self-transformation and increasing performance, the cluster faces the same challenges as the rest of the automotive industry in Germany: without achieving continuous innovativeness, quality and diversity, the tables can turn very fast as they did in 1990s.

4.4. Software services for automotive industry and the Stuttgart region

In general terms, software services can be divided into four main groups: platform development, software production, consultancy and after sales services (Table 11) (Isaksen 2004 pp. 1165-1167). These activities form parts of the software services supply chain and individual firms often undertake several of these activities simultaneously.

Table 11: Main activities in the software services industry

Firms/activities	Products/services	Important clients	Requirement for the knowledge of client-processes
Platform suppliers	Basic technology and tools	Software producers and consultants	Low/medium
Software production	Standard software solutions	Organizations that need 'simple' ICT solutions	Medium/high
Special applications production	Dedicated solutions for specific applications	Organizations that need specialized and customisable solutions	High
Consultancy	Tailor-made ICT solutions, advice	Advanced ICT users	High
After-sales services	Training, support, running IT-systems	All types of organizations	High

Source: Isaksen 2004 p. 1166 and own inputs

Software platforms are composed of relatively generic software applications and tools. Besides offering a basic functionality set, some of them bred diverse solutions, as in the case of Microsoft (e.g. the ubiquitous Microsoft-office suite), SAP (enterprise resource planning software) and Oracle (database management software) products. The second group, “software production”, supplies standard and near-standard software packages with specific functionalities (e.g. accounting, customer relationship management and logistics). These solutions are implemented by users with varying degrees of modification and often require additional consulting and after-sales services.

The third group is related to the second, but has a deeper level of specificity in terms of application areas i.e. these software solutions are conceptualised and developed for dedicated sectoral areas, hence they require a detailed understanding of the characteristics of customer sectors. Consulting services are tailor-made solutions, i.e. the development and implementation of new or derived software solutions to satisfy specific customer needs. These services are closely linked to the internal processes of clients and require a detailed understanding of the clients’ organizations and processes. Business advice is often part of software consultancy. The general lines of activity of the last group, after-sales services, include training, infrastructural support in terms of maintenance, management of client systems and problem-based technical support.

The automotive sector uses all five groups of services represented in Table 13. While some of the software applications used in the automotive industry is nearly identical in terms of purpose to that of other industries (e.g. tools for basic communication or for peripheral enterprise activities such as accounting), others are highly customized or specially developed automotive applications. This study focuses its attention on the latter group, i.e. special application developers that also offer consultancy and after-sales services. Depending on their areas of installation and the ends they serve, automotive-oriented software applications can be split into two main groups: in-product and process-oriented software. The in-product software is contained predominantly in EE systems, which largely consist of embedded-systems that depend heavily on software content for their functionalities. Process-oriented software very nearly covers all processes in the automotive industry.

Before defining software services for automotive industry in more detail, statistical data relating to the software services activity in Stuttgart region in general will be presented. With a share of about 2% by the end of 2006, software services do not play a dominant role in terms of regional private sector employment. Despite the 7.6% increase in the total number of firms, the employment in the software services sector in Stuttgart region remained around the 18.000 mark between 2004 and 2006 (Table 12). In comparison, again according to Business Register statistics, the automotive industry's share of total employment was 14.11%. The yearly structural report commissioned by the regional Chamber of Commerce reports the statistical group "computer and related activities"[51] to have with 26.000 wage-employees in 2006, which corresponds to a growth of 37.6% since 1999 (IMU/IAW 2007 p. 164). The classification differences aside, this growth reflects a positive development, which also beats the overall growth of enterprise services in the region in the same period (27.2%). On the other hand, despite the large number of enterprises, a significant portion of employees works for the large enterprises like IBM, HP and Alcatel (IHK Region Stuttgart 2007a).

[51] This statistical classification group includes hardware consultancy and maintenance activities over software services.

Table 12: Software services firms in Stuttgart, 2004-2006

	No. enterprises			No. employees		
	2004	2006	+/- %	2004	2006	+/- %
Software consultancy and supply	1.852	2.085	12.6	12.989	14.295	10.1
Data-processing	495	474	-4.2	3.819	2.972	-22.2
Database activities	14	18	28.6	90	215	138.9
Other computer rel. activities	307	295	-3.9	1.236	1.289	4.3
Software services total	2.668	2.872	7.6	18.134	18.771	3.5

Source: Business Register

As previously discussed in Section 3.2, it has proven impossible to identify the exact number of automotive-oriented software services firms in Stuttgart region. Through inquiries to available databanks and other resources, it was possible to identify 84 firms that have software services for automotive industry as their focus. This number does not include software-intensive engineering services although some of these firms cite these on their portfolio. However, employment statistics provide some hints at an increasing automotive focus at software services firms. Firms from the statistical classification sub-groups "software consultancy and supply (72.2)" and "data-processing (72.3)" have been employing an increasing number of engineers to carry out tasks associated with automotive, mechanical and production. Such a clear and strong trend (377% in eight years) implies a growing demand for automotive and mechanical engineering related software services. Remembering the similar growth trend in terms of IT and software engineering related tasks at automotive firms (Table 13), it can be inferred that this growth in internal and traded activity in software-related tasks has not affected each other negatively till now.

Table 13: Employees with mechanical, automotive and production engineering related tasks at software services firms, 1999-2007

	Software consultancy and supply and data-processing services				
	Mechanical and automotive engineering	Other production engineering	Other engineering	Total	Growth trend (1999 = 100)
1999	21	68	97	186	100
2000	26	75	142	243	131
2001	20	79	159	258	139
2002	23	69	164	256	138
2003	27	63	256	346	186
2004	76	71	360	507	273
2005	109	55	459	623	335
2006	128	57	568	753	405
2007	135	65	688	888	477

Source: Federal Employment Office, own calculations

In-product software in the automotive industry

As was mentioned in Section 4.1, EE systems are the key enablers of almost all critical functionality in a motor vehicle. The basic unit of an EE system in a vehicle is often an embedded-system, which is "a combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function"[52]. The use of embedded-systems in motor vehicles began about 30 years ago when auto makers started to manage certain functions such as engine management and ABS system electronically (Broy 2006 p. 33, Pretschner et al. 2007 p. 1). Since then, their numbers and the amount of software have increased exponentially. Today on-board networks in a medium-sized motor vehicle contain above 70 processors compared to just 6 discrete units a quarter of a century ago and the amount of code goes up to 10 million lines in a single vehicle (Otterbach 2008, Grimm 2003 pp. 498-499).

Compared to process-oriented applications, in-product software has a deeper automotive-orientation. Embedded-systems are designed and developed to carry out dedicated functions in specific environments, so they are literally custom designs for specific vehicles. While

[52] Embedded Systems Glossary. [Online]. Available from: http://www.netrino.com/Embedded-Systems/Glossary [Accessed: 7th March 2008].

functionality of some of in-product software is directly accessible to the driver and passengers (e.g. navigation, multimedia and other MMI software), most operate without requiring any direct input (e.g. infrastructure software, software for safety electronics, power train and chassis control software) (Broy et al. 2007 p. 7). Another crucial point is the fact that in-product software applications function in cross-connected on-board networks, such as CAN or MOST [Media Oriented System Transport] bus systems. Such connectivity means that a vehicle "turns from an assembled device into an integrated system" (Broy 2006 p. 34) and the behaviour of one component, i.e. a given embedded-system unit, affects others through input-output relations in and between networks.

Technically, embedded-systems consist of dedicated combinations of hardware and software. Software plays the crucial part in an embedded-system by defining the borders of hardware-functionality and between 50 to 70% of the costs of a control unit is software related (Krust 2008). The main challenge in the development of an embedded-system is to create a mixture of high performance, low weight, size and cost. Till today, the dominant development approach in the automotive industry for electronic components has been to maximize hardware utilisation. This approach is commercially motivated by the fact that purchasing contracts have traditionally been based on units of hardware. Indeed, when electronic components were introduced first, OEMs remained unwilling to pay for software development at all.

In order to reduce the costs for hardware, suppliers have been trying to get as much performance as possible out of the smallest possible memory capacity (Broy et al. 2007 p. 4). In other words, software would be customized to exploit control units to the limit in order to reduce the hardware capacity required for an application. Although it reduces hardware costs, such a dedicated customisation of software for a single piece of hardware forecloses its portability elsewhere (Hardt/Feldo 2007 p. 6). In addition, a very small amount of code would be shared across systems on a vehicle and with each new model generation the development would have to begin from scratch. An organisational consequence of this paradigm have been the difficulty for the automotive firms to separate the development and hence the purchasing of software and hardware components for embedded-systems.

Such an approach led to very little inter-industry cooperation in standards development, which in turn caused the cumulative costs for software development and system integration to explode. Even today, despite relatively long-standing initiatives like MOST, the level of standardization and integration for software development is insufficient in the automotive sector (Pretschner et al. 2007 pp. 4-5). As a consequence of the limited cooperation and the lack of standards, proprietary technology environments have grown around OEMs and large suppliers like Bosch and Continental. Another consequence is the shorter supply-chains as compared to physical components and the large amount of work done by Tier-I suppliers.

Process-oriented software tools

These tools can be grouped according to their target market specificity. All four main sub-sets of the vehicle development chain (product and production engineering, logistics and customer relations management) depend on IT-tools in similar measures (Fig. 17). Some of these tools are developed exclusively (or at least primarily) for the automotive industry, yet others are derivatives of fundamentally industry-independent software. Examples of these “generic” enterprise IT-applications are sector-independent business process management applications (e.g. communication, eBusiness, project management). Although these tools require sectoral adaptation, this is not as far-reaching as to deserve an automotive-oriented tag. The IT-industry in Stuttgart region has many enterprises that offer these services to the automotive cluster. The second group of applications, which is the main point of interest for this study, is either developed exclusively for the automotive industry’s needs or include a comprehensive re-working to fit the purposes of this industry. It would be impractical to provide an exhaustive description of all the software tools used in the automotive industry, therefore only selected applications are represented here.

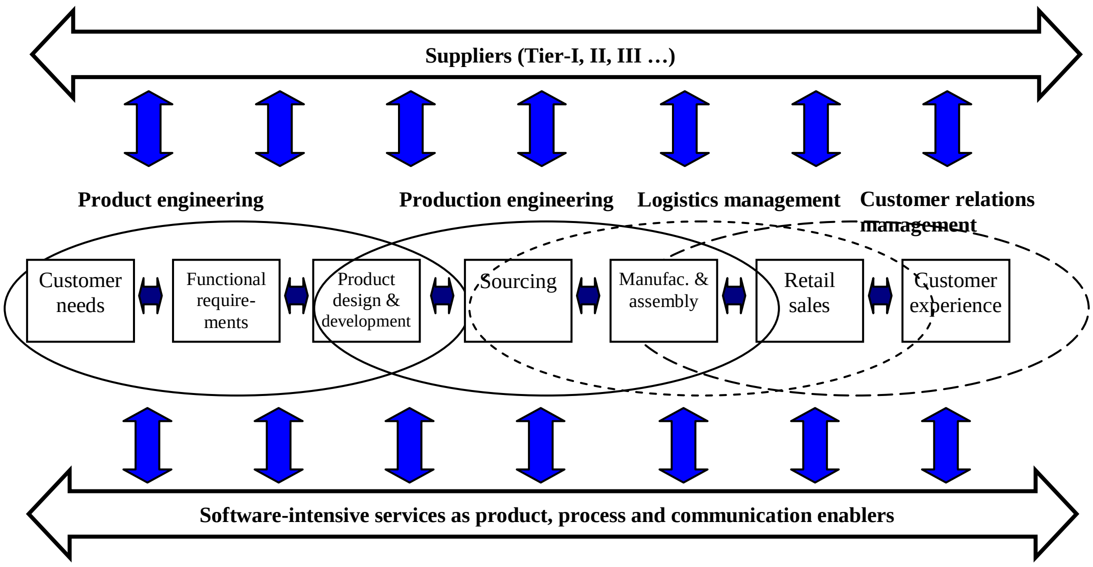

Fig. 17: Associations and activities in vehicle development chain

Source: Own representation

To begin with the first component, product engineering, one must first acknowledge the organizational paradigms in automotive product development. In contrast to the sequential flow of activities in the past, in the post-Toyotaist world parallel-running processes across functions, organizations and locations is the norm (Fig. 18). Such process organization is born out of the need to accelerate development processes and decrease costs. Large OEMs operate global networks of locations where R&D and product development work is carried out in close cooperation with suppliers.

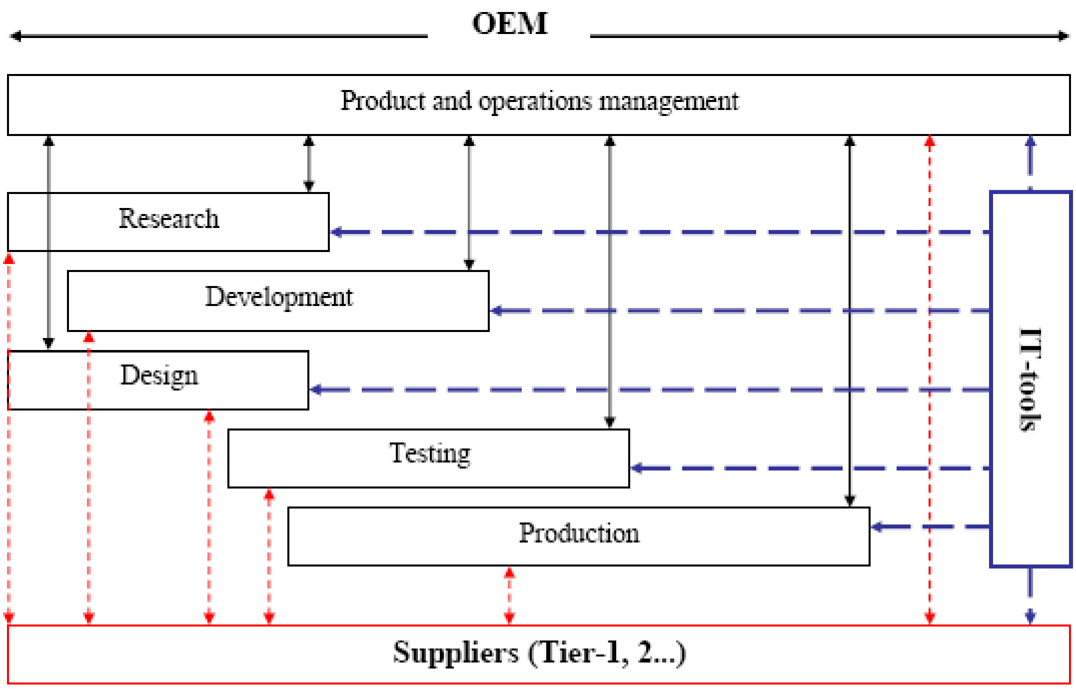

Fig. 18: Parallel-running lean product development processes in the automotive industry

Source: Own representation

IT-applications are the main enablers of these complex processes in that they facilitate communication, data-sharing and collaborative activity across the supply chain. In order to shorten development times and early identification of potential product problems, automotive firms are digitalizing product development and introducing engineering analysis sooner in the development cycle (Nobeoka and Baba 2001 pp. 63-65). This approach, called “concurrent (or simultaneous) engineering”, stimulates the parallel and distributed execution of tasks. Added benefits are faster reactions to market signals and the ability to use common parts and tooling across products. In practice, concurrent engineering involves the use of CAD, analysis, modelling and simulation applications, quality assurance methodologies, communication and management tools. Besides fulfilling their task-specific functions, these tools stimulate a degree of cognitive proximity among process participants across internal departments and company borders by building a common visual basis. CATIA[53] is currently a central component of the CAD product development software stack in the German automotive industry. Due to the integrated role played by the CATIA platform in vehicle development, engineering services providers are also intensive users of this software application. Technically, it consists of a powerful software core that acts like a platform together with complementary applications and customer-specific modules.

A software application domain with a growing significance for automotive industry is the simulation and virtual reality. This group of applications enables the pre-physical visualisation and testing of components, systems and processes through virtual prototypes. This reduces the need for the expensive physical prototyping and tooling, while eliminating potential errors and problems in advance through integrity tests and suchlike (Dunker 2007). Another important function of virtual reality technology is its ability to create a common visual (and hence cognitive) platform of proximity for individuals from different knowledge backgrounds. For instance, the virtual 3D representation of a future model allows product designers, development engineers, purchasing and manufacturing specialists to achieve a common understanding on which they can communicate (Löwer 2008). Although the implementation costs had been quite high during the early days of the technology in 1990's, the cost-performance ratio of computerized simulation systems and virtual reality technology has been increasing massively due to decreasing IT-hardware prices. Consequently, the diffusion of these applications across the automotive industry has also been expanding. Virtual crash tests are another impressive example of how software tools change development processes in the automotive industry. Physical crash tests are highly critical and indispensable parts of vehicle development. These tests involve very high costs for the simple fact that a single physical crash test costs nearly one million Euros. OEMs have been using computerized crash-simulation increasingly, which not only leads to reduced costs, but also shorter development times as the less number of physical tooling and prototypes are required. For both simulation and virtual-testing software, it is possible to speak of increasing returns (Storper 1997 p. 62). As a result of their use, such software tools lead to the development of databanks of knowledge and experience plus know-how across a firms' workforce, which eventually increase the returns an enterprise derives (e.g. processes require less time with each new product generation and the results become ever better representations of physical tests).

[53] CATIA (Computer-Aided Three-Dimensional Interactive Application) is a multi-platform CAD/CAM/CAE (Computer-aided design/Computer-aided manufacturing/Computer-aided engineering software) suite that is widely used by the automotive and aerospace industries.

For the production engineering stage, an interesting extension of the digitalization trend is the "digital factory/manufacturing" field. The aim is to model the production premises with their activities. Such a system would ultimately help industrial companies to plan, optimize and resolve production flows and logistics issues (Westkämper 2002). In the pre-production start phase, it can be utilized to visualize and simulate working places, production flows and possible scenarios for devising an optimum state. After start of production, the software can assist the management of production flow.

An important extension of the industry-wide digitalisation trend is PLM (Product Lifecycle Management), which is the activity of managing a firm's product-related information along different products' life-cycles and across company borders. From its beginnings with simple engineering databases in the early 1980s, the PLM approach at once evolved into an engineering tool and business strategy, linking the knowledge needs and resources between customer demands and development, manufacturing, purchasing and quality processes (ibid. pp. 227-231). Apart from its implications for process management, from the IT-perspective this involves linking numerous software applications (software-aided design, computer-assisted manufacturing and computer-aided engineering and others). Thereby, automotive firms try to manage the exploding complexity and dynamism of their product portfolios by joining information, people and processes under a single framework.

The need to manage the costs of operations given the cooperative nature of modern-day product development and manufacturing processes has turned enterprise resource planning (ERP) and supply-chain management (SCM)[54] software applications into mission-critical tools. Put very briefly, these processes aim to increase total productivity and profitability by helping processes to become leaner and faster. ERP stands for a broad set of activities that help an enterprise to manage all facets of its operations (e.g. marketing, finance, sales and manufacturing) (Huang/Palvia 2001 p. 276). While ERP largely deals with internal processes, SCM incorporates the management of activities across the firm's borders. SCM processes practically cover the chain of activities from the supplier to the customer and support these processes with software functionalities. These software tools not only acquire and process data, but also partake in the planning and execution of process decisions (Helo/Szekely 2005 pp. 5-7).

[54] Supply chain management is referred to as "the systematic effort to provide integrated management to the supply value chain in order to meet customer needs and expectations, from suppliers of raw materials through manufacturing and on to end-customers" (Stein and Voehl in Sherer 2005 p. 79).

The agglomeration of software services activity in Stuttgart region contains enterprises that offer software products and services in the above mentioned application areas. Indeed there are several indigenous software enterprises that develop products that are competitive at the national and European levels. Besides, there is a strong representation of non-local software firms through subsidiaries. Although, the exact number of automotive-oriented software services firms cannot be determined due to lack of comprehensive data, it is possible to identify over eighty software enterprises in Stuttgart region. Especially the local OEMs and Tier-I suppliers appear as important customers for these firms and it is an exception to find a software firms that does not list them among their references.

A dedicated cluster-facilitation agent for software services activity for automotive industry is missing at the moment; there are distributed efforts that stimulate regional interaction. For instance, automotive sector applications are the leading thematic area for Virtual Dimension Centre (VDC) Fellbach, which is a regional network that specializes in virtual reality software solutions. Regional networking activities targeted at IT and general software services fields, for instance WRS or MFG, are also partly covering automotive-related topics. Even the regional venture capital networks, such as the Business Angel Forum Region Stuttgart and South-West Technology Funds, partly support the development of this area. Supra-regional links are also observable at the firm and regional level. An investigation of the reference customer lists of identified firms reveals the presence of customers outside the region and at the regional level, numerous automotive-electronics and software themed congresses and conferences provide an additional platform for knowledge exchange with specialists from outside the region. Therefore, a closer look at the intersection between automotive and software sectors in Stuttgart region suggests indications of a sub-cluster, which, despite a considerable level of activity, buzz and active global knowledge pipelines, goes unnoticed in statistical data.

4.5. The weight of the “Lastenheft”

The development of new motor vehicles involves the preparation of requirements for the performance of the components and systems. A requirement, in its basic meaning, defines what a system must be able to do and “how well” it has to do it, but not necessarily what the implementation must look like. During the course of software development, requirements are created, shared, discussed, re-written and transformed into solutions. Requirements engineering refers to the elicitation, specification, modelling and management of these tasks internally by OEMs and suppliers (Grimm 2003 p. 501, Broy et al. 2007 p. 5) and requirements management involves the complex and dynamic task of requirements tracking and verification processes (Almefelt et al. 2006 p. 113). A sound performance in this area during early development is a must for preventing costly changes in later stages.

The requirements gathered by the customer are formalized and codified in the user requirement specification document (in German “Lastenheft”) (Weber/Weisbrod 2003 p. 19). This document basically describes what the customer demands, or in other words what the problem is, together with the boundary conditions thereof. In response, the provider prepares the “supplier system specifications”, or in German “Pflichtenheft” (ibid.). Here the supplier explains the solution it envisages for the user problem. Not surprisingly, this whole process is accompanied by a basic communication challenge, caused by the divergent perceptions of two parties regarding concepts and terminology. While customer defines the requirements to the best of their knowledge, they do so by utilizing their own “alphabet”, which could differ from that of the software supplier.

Although the specifications document goes through several versions before the legal contract for a project is signed, a perception gap, created by the divergent “alphabets” of parties, remains. Consequently, the solution document goes through further versions as the requirements evolve in the course of the project, so that “change and discussions about change are part of daily project life” (ibid. 21). Ambiguities in specification sheets or interpretative gaps between the suppliers of different systems lead to integration complexities in later stages. Worse still, some problems go unrecognized during development and surface again when customers are at the wheel, eventually causing damage to OEMs’ reputations and sales. Often, insufficient software development maturity and incompatibilities among different on-board networks are the reasons for these problems and are indicators of the underdevelopment of software development in the automotive industry. Complexities of software development are only beginning to be thoroughly comprehended by OEMs and suppliers, and suboptimal development practices are fairly frequent (VDA 2003 p. 59, 2004 p. 111).

When asked if more engineering activity would be transferred to low-cost locations, Klaus Borgman, a high-ranked development manager at BMW Group, answers: “This will be limited to relatively clearly defined work-packages. This means, the specifications must be clear, and must be part of isolated assignments. Complex problems, for which an interaction between the staff at different departments [at BMW] is necessary, I see the emphasis on central [internal] locations" [Borgmann 2007]. Development of embedded-systems poses such complex problems.

Because tacit knowledge is contained in humans and is context specific, it is argued that it travels imperfectly over geographical space (Gertler 2003, Morgan 2004). The significance of "Lastenheft" comes from its character as a tool for the conversion of tacit knowledge into an explicit form. To be able to produce Lastenheft on a software development problem is clearly the first step in involving an outside party. As the codified expression of a customer's demands, preparation of the Lastenheft is a time-consuming process that includes detailed discussions. As the text includes more detail, a common understanding of the problem is formed. At the same time, both sides gauge each other's respective knowledge and skills.

The availability of a Lastenheft document reduces the need for personal contacts and thereby frees the customer partly (although not completely) from the obligation to work with locally available providers. Indeed, a department manager responsible for crash simulation and related software declared:

> *"We make a distinction between development activities where one can and cannot define "packages". Once I have defined such a package, I can send it on to anywhere."* (Interview 22, translated by author)

As claimed in literature, tacit and explicit knowledge are actually complementary entities and need to be considered together (Nonaka 1994 p. 19). Having a Lastenheft on hand does not rescind the need for communication, and a combination of ICT tools and personal meetings are still required for the progress of development. However, the codified knowledge basis created by Lastenheft reduces the frequency for personal meetings and allows delocalised development.

However, there are cases when preparation of a Lastenheft is not possible – for instance when the possible contents of the document are too close to a firm's core activities or are too tacit and dynamic to be codified. The lack of a standardized set of approaches and tools are also a hindrance as it does not allow the development of comprehensive system models (Pretchner et al. 2007 Sec 2.2). One interviewee remarked on how his firm could not involve a services provider to develop the simulation software required:

> *"Software services firms need detailed specification documents. But we could not prepare these at the time because we ourselves did not know what we needed"* (Interview 12, translated by author).

In other words, uncodifiability of knowledge and knowledge production processes restricts the division of labour across enterprises. In such cases, the firms can potentially carry out the software development in-house, as this last firm did with the simulation software. However, if they do not possess the necessary know-how to undertake parts or the whole of the software development, they choose to bring in specialized software suppliers to work on their premises. Both options satisfy two conditions; firstly, a close, detailed and rapid interactive knowledge exchange is ensured between the software developers and the experts who possess the area specific tacit know-how. Secondly, working in close quarters or within the same organisational borders, automotive firms ensure that unwelcome knowledge-spillovers are limited.

An interesting development that can eventually change the organizational and geographical distribution of development activity is the observable increase in cooperative initiatives for standards development in the automotive-software domain and German-owned firms appear to be most active. Important examples are the HIS[55] initiative of German car makers, which aims to define harmonized interfaces to reduce supplier effort to adapt to different OEM requirements, and "Automotive Electronics Innovation Alliance", which was mentioned briefly in Section 4.3 (Chodura et al. 2004 p. 48). As mentioned previously in Section 4.3, the latter aims to develop basis-EE hardware architectures, interfaces and standards that would be implemented across all model and price segments.

The most ambitious and important of the initiatives however is the AUTOSAR consortium[56], which is a joint action of over ninety OEMs and suppliers. It aims to establish standards for the development and operation of electronic components on vehicles. In technical practice, AUTOSAR addresses the internal functioning of individual embedded-systems and communication across their networks for all sub-application domains with standardized protocols and methods (i.e. body-electronics and power-train management). Here, portability on different hardware and re-usability of software has priority, as opposed to extracting the highest efficiency. Most importantly, AUTOSAR aims to give engineers a common language and reduce the efforts required for integration, testing and assurance (ATZelektronik 2008).

A sign of the mounting interest in AUTOSAR is the number of related contributions in industry relevant congresses and symposia in recent years. The final version of this standards

[55] HIS (German: Hersteller Initiative Software): "Car Manufacturers' Software Initiative. "

[56] Actual information about AUTOSAR (AUTomotive Open System Architecture) initiative is available at: http://www.autosar.org/find02_ns6.php [Accessed 20 March 2008].

package is planned for the end of 2009 and the first vehicles to contain AUTOSAR-components are expected to reach markets in the near future. If successful, AUTOSAR can bring a new degree of freedom for OEMs and large suppliers to separate hardware and software development, which will eventually lead to a new degree of division of labour across the supply chain. More flexibility in the geographical distribution of activities can also be expected, as the AUTOSAR standards establish themselves and provide a common language of codification across the industry.

4.6. The dimensions of proximity for KIPS customers

4.6.1. In-product software development domain

The development of in-product software differs from that of other (physical) components found on a motor vehicle. The engineering processes relating to mechanical components and systems have a century of improvement behind them, and today they function through relatively mature interfaces and standards. Due to reasons discussed in detail in Section 4.4, the process and software standards in the younger in-product software domain are still in a state of work-in-progress and supply-chains are often shorter than for physical components.

Embedded-systems, where majority of in-product software is contained, are mostly parts of electromechanical systems. They provide the complex functionality that allows vehicles systems to behave “intelligently”, for instance like a rain sensor equipped windshield wiper that senses the severity of the rainfall and adjust wiper speed automatically. In this case, the Tier-I windscreen wiper manufacturer would deliver the whole system that includes the mechanical components, optic sensors and corresponding control units. The same applies for other systems and modules on vehicles as well; therefore one of the development tasks of the vehicle manufacturer is to ensure compatibility of software from different sources. Besides integrating different components into a functioning system, vehicle manufacturer also carries out the development of software functionalities that serve for brand differentiation (Grimm 2003 p. 500).

The core knowledge (or the core competency)[57] of a Tier-I supplier today includes the ability to design and develop complete modules, including embedded-systems. Hence, software development processes are of utmost priority and weight for top level suppliers. A software development manager in a Tier-I supplier from Stuttgart remarks:

[57] Core knowledge of an enterprise relates directly to the fundamental competencies that allow it to beat competition and remain in business (Larsen 2000 p. 151).

"We develop the control units and the software that goes with them. Software itself is a significant factor in the functionality of the product [in general]. This is where our core-competency lies, which we like to keep in-house…" (Interview 11, translated by author).

As it is designed dedicatedly for a specific application, the development of a software component is too close to the general design of an electromechanical system. Due to the underdeveloped software standards and protocols, the possibility of separating software development from area specific know-how is limited. Hence, loosing the close-to-customer know-how that brings these suppliers a competitive edge over their rivals is a real risk. Therefore, for most Tier-I suppliers only peripheral activities such as documentation or testing are possible candidates for outsourcing. Even for these tasks, large suppliers tend to engage outside service providers who have already worked on contracts for them.

Complexity, parallelisation and time pressures force developers to introduce assumptions early on in development, which then need to be worked out as the system matures. Some of these changes are unplanned and unforeseen and can pop up anywhere: in applications, component requirements, schedules, responsibilities etc. (Weber/Weisbrod 2003 p. 21). The questions that arise are often interwoven and bounded by uncertainties at the system level. The necessary communication to agree on possible solutions is complex and needs to be rapid. The development engineers are often not always capable of formulating the problems and solutions in so many words and secondly, possible paths of solution are devised by utilizing experience-based personal know-how. The knowledge content of these exchanges is often new and highly tacit and the interactions themselves are sources of knowledge-production. The solutions to these technical problems require an intensively interactive dialogue of "interruption, repair, feedback and learning", which can be carried out more efficiently through face-to-face (F2F) interaction (Section 2.1.1, Storper/Venables 2004 p. 47). Therefore the development processes of in-product software demand a considerable amount of spatial proximity. A punch-line-perfect summary of these notions was expressed by a development engineer at a Stuttgart-based engineering services firm as follows:

"One needs geographical proximity when things go wrong." (Interview 28, translated by author).

Specialized engineering and development services firms are another important group in the in-product software field. Their services include the creation of development tools for automotive embedded-systems, development of embedded-systems themselves and optimisation of software and hardware integration, among others. As is typical in the field of development engineering services, these enterprises are often located in the spatial vicinity of their customers, OEMs and Tier-I suppliers. Table 14 provides an overview of the regions where a selected group of leading engineering services firms are located in Germany. Indeed, a Stuttgart-headquartered enterprise that specializes in on-board electronics has an office in Munich on the same street as FIZ, the central development centre of BMW Group and in Ingolstadt the firm's bureau is only a couple of minutes away from the Audi premises. The firm originally chose Stuttgart region due to the spatial proximity to the development centres of Daimler, Porsche and Bosch. The main reasons for such a follow-the-customer strategy can be found in the cognitive dynamics of the development process, which was described above and in the characteristics of vehicle development and testing practices.

Table 14: A selection of engineering service firms and their locations in Germany, 2008

	Ingolstadt (Audi)	Munich area (BMW)	Stuttgart region (Daimler, Porsche and Bosch)	Cologne area (Ford)	Darmstadt area (Opel)	Wolfsburg area (VW)
AVL		x	x	x	x	x
Bertrandt	x	x	x	x	x	x
dspace		x	x			
Gigatronik	x	x	x	x		
IAV	x	x	x		x	x

Source: Own representation

Beside the spatial proximity requirements arising from frequent F2F interactions, there are also process specific matters that make co-location with customers indispensable for development services providers. An important part of vehicle and embedded-system development includes tests on vehicle prototypes. Such tasks are often carried out with dedicated equipment that is very costly to be duplicated elsewhere and the secrecy surrounding new models does not even allow some prototype vehicles to be taken out of an OEMs' premises. Therefore, in some cases there is little choice but to set up subsidiaries where the customers are and to carry out tasks on the customer's site.

Then again, in cases where challenges related to requirements management are manageable and cost and performance advantages present themselves, OEMs do not hold back. For instance, according to a high-ranked development manager at BMW Group, his firm would undertake the development of a new navigation system in Munich but its language adaptation can and would be outsourced to a local firm, because this would be an easy to define task that is best be done by developers with necessary local market know-how (Borgmann 2007).

On the other hand, there seems to be more scope for the delocalisation of in-product software development within the borders of an enterprise. Two of the Tier-I suppliers that were interviewed for this study share software development tasks with internal teams located in lower-cost countries. The first is a supplier of electromechanical vehicle systems with software development support unit in Cairo, Egypt. The reasons for the locational choice are numerous: the cost advantages, being in the same time zone, relatively short flight distances, the availability of qualified labour and the presence of IBM as a joint-venture partner. However, the team in Cairo carries out only peripheral parts of development process such as testing based on detailed designs and module specifications that have been completed in European locations. The interviewee states that effort was required to synchronise processes and establish a common understanding of issues, but once the organisational and cognitive proximities are established, the activities function satisfactorily.

Another example is a large Stuttgart-headquartered supplier that deploys a Budapest-located team for the development of control-units for powertrain systems. The overall development work is coordinated and carried out by a dedicated department in Stuttgart, which also conducts similar development activities for other suppliers and OEMs. A subordinate unit located in Budapest was created in late 1990s and today it reached half the size of the Stuttgart development team. The pre-existence of manufacturing operations for control units was a strong motive for the choice of location. While the overall coordination of projects remains in Stuttgart, the team in Budapest undertakes and manages portions of sub-system development under its own responsibility.

According to the declarations of the interviewee, the quality of education in Hungary provides a good basis for capabilities on which a cognitive proximity to the team located in Germany can be built. Cognitive proximity in this example comprises the necessary understanding of the components and the associated automotive development processes. In addition, the supplier in this example wanted the Budapest team to absorb the enterprise culture of the parent company and to build personal relations with counterparts in Stuttgart. In other words, the supplier wanted to establish cognitive, organizational and social proximities between the spatially-distanced teams. To achieve this, members of the Budapest team are invited for prolonged stays in Stuttgart and learn the German language, all of which is sponsored by the supplier. Despite all these efforts, the interviewee states that a consideration for intercultural matters, or – in other words – a consideration for institutional distance, is required in order to prevent friction on cooperative projects. For instance by paying attention to how criticism should be expressed or to how project management habits differ. Besides, additional training investments and regular site visits have been necessary.

Both examples underline the importance of organizational proximity in distanced knowledge-intensive activities. The uncertainties embedded in services transactions are amplified by geographical distance and political borders, because capabilities of observation recede with distance and institutional gaps create legal insecurities and amplify the costs for legal security. Maximizing organizational proximity reduces uncertainty, as knowledge eventually remains within the borders of the enterprise (Larsen 2000 p. 148). Besides, in the case of serious problems during development projects, organizational proximity enables faster solutions, namely without indemnification or legal proceedings.

The differences between the two cases are also telling. In the first example, activities are shared, but the complexity of tasks is kept at a low level and the requirements regarding cognitive and social proximities are relatively modest. The supplier creates itself an access to a low cost base without transferring much knowledge to this offshore location. However, in the second case the objectives are more ambitious and more complex tasks are carried out independently by a spatially distanced team. Hence, the firm is compelled to invest significantly in building and maintaining the cognitive, social, organizational and institutional proximities. Thus, it is possible to conclude that high organizational proximity can ease spatially-distanced relations, as it removes concerns about trust and knowledge-loss to outsiders. However, when the knowledge intensity of processes increases, the necessity for other aspatial proximities rises.

4.6.2. Aspatial proximities and process-oriented software purchasing decisions

In the "focusing on core competencies" world, developing the necessary process-oriented software applications does not appear as the first choice for automotive enterprises. Therefore, purchasing and appropriately adapting a commercially available software solution is preferred and the process-oriented software stacks of automotive firms are very often a mixture of standard and customized layers. Cost is a primary motive for this strategic behaviour, as the necessary effort to bankroll the development of a whole software stack goes well beyond the respective and cumulative advantages the software applications bring and is not economically feasible. As such, outsourcing decreases the depth of internal software development activity in an automotive enterprise, while focus shifts to requirements management and process coordination.

Things have not always worked in this fashion though and automotive firms used to be involved more deeply in software development. An IT expert at a local OEM, who deals closely with the CATIA-environment, says:

> *"The amount of work done outside the firm has changed immensely…Even during the times of CATIA V4, we needed [to develop] additional applications [internally]. What has changed is…now a lot more is done outside the firm…For CATIA V5, at the beginning there were complete departments in our firm that carried out the applications. It is not like that anymore, it is only a small portion now. Of course we did contract things out at the time, like we do today… to almost the same providers [we have today]… But it was not as…let me say… fast-moving. Similar to how our own products, a car or a [manufacturing] tool, have shorter life cycles, one expects the same of a software product…"* (Interview 16, translated by author).

A good example of the change in software development and purchasing decisions of automotive firms is the dealer management applications. Dealer management software is the solutions package, which helps the management of processes (e.g. CRM, stock management and financial control) at the retail end. Although these software packages are installed at dealers' premises, they are often closely watched and even coordinated by OEMs. Dealers across the globe are invited to use the same application, which is chosen by the OEM from a select number of multi-platform and multi-language software packages. These multi-platform solutions have almost semi-industry standard attributes and vehicle manufacturers do not object to their competitors using the same software. A local OEM that uses one of these semi-standard applications formerly employed a system that was developed in-house, because alternatives on the market were scarce at the time. A representative, whose area of work includes the coordination of the use of dealer management software at this OEM, says:

> *"It makes no sense to reinvent the workshop management system for the n^{th} time, when there is nothing in this application that would help you differentiate yourself from competition in some form…If a standard application is available, and there is no need to differentiate yourself from your competition, if the processes and functions are the same, one does not need to invent it again... But when we speak of standard systems, we speak of standard systems that go through customization. The interfaces are specific to us and special functions and processes that differentiate us from our*

competitors are introduced, with the hope that these will separate us from the competition." (Interview 29, translated by author)

Decision process

For large-scale software applications, e.g. CATIA V5, a lot of incremental innovation is realized as additional pieces of code or modules to be written and implemented. When the need to develop a new functionality appears, an automotive firm has basically three options: having the software producer implement the changes in the main software, hiring a third party to write an additional software module or doing the work in-house. The functionally ideal solution for automotive firms appears to be when the producer of the software application carries out the necessary development. However, software firms are not always prepared to confer to all customer requests. A representative of a software firm declares that when a technically applicable customer request arrives:

> *"…we have to see if it would fit to be added to the main product for all customers or if it serves a customer-specific matter. Is it only an isolated [customer-specific] case or is it a case for product improvement?"* (Interview 26, translated by author)

To have the software producer carry out the changes is the most convenient option, as it secures the compatibility of the amendments with future versions – in order words; the problem is solved at the source. Yet, should this not be possible, the option splits into do-it-yourself in-house or engaging a third party. The decision for third parties is the next best solution, because

> *"(these) applications function exactly like CATIA V5 does; basically there is no difference to be seen from the outside. It is also ensured that these applications will be in the state that I need them. We purchase maintenance contracts [at the same time] and [service providers] maintain the whole thing for us."* (Interview 16, translated by author).

In comparison, carrying out these changes in-house comes with lower initial costs, but consequent maintenance or debugging efforts increase costs in an unpredictable manner, which makes it a less desired option. All considered, the decision process is depicted in Fig. 19.

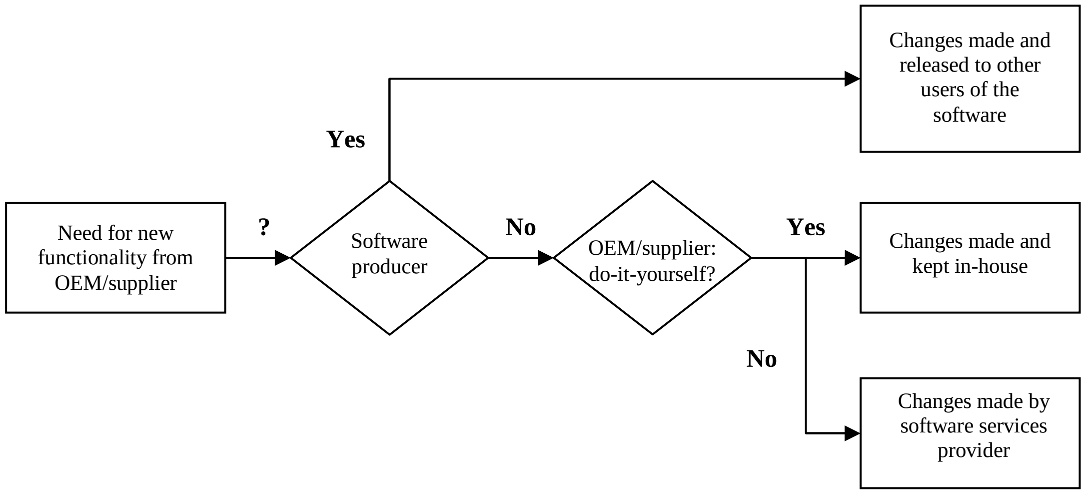

Fig. 19: Decision process for software services purchasing

Source: Own representation

When asked about the criteria for choosing a software supplier, the representatives of automotive firms replied with different words to similar effect: “skills”, “competencies” and “know-how” (Interview 16, 19, 20, 22, and 23). Clearly, the cognitive dimension repeatedly appeared to be the primary criteria for supplier selection. However, on top of software know-how, automotive firms look for an additional layer of automotive sector literacy in their software services suppliers. A department manager at a local OEM, who is responsible for activities that use crash-simulation and related software exemplifies this when he states:

> *“[The personnel of the software services provider] have to understand that the colleagues in my department are not software specialists. We are software users. We are automotive specialists… If I speak to a service provider and he does not understand what I need as a user, it is very difficult to work together. In other words, I need someone in a software firm that knows and understands what I need, who can, let me say, speak my language. I can’t get anywhere with someone who only thinks software ….someone, who has a good feeling for what I need because I can only approximately express what I want…This is not so easy [to find].”* (Interview 22, translated by author)

“Having a common language” refers to a common stock of special technical terminology and customary expressions, which are specific to respective domains in the automotive industry. Such distinctive language and sets of codes facilitate knowledge exchange and production in specialized communities of practice (Willcocks 2004 p. 12). For the supplier, this complex means of communication is the transaction-specific product of an accumulation process that runs through customer projects. The same interviewee from the last quote remarks:

> *"The service provider should – as far as possible – have done something similar [to what we require]; he must be able to implement this topic [in a crash test simulation environment]."* (Interview 22, translated by author)

Customer-specific cognitive proximity is also a product of previous experiences and involves elements related to customer's products, processes and strategy. A manager at the central IT-strategy department of a local OEM states:

> *"One of our targets is to decrease the number of [software] suppliers we have and to concentrate on a fewer number of strategic partners. Because the longer we work with a company, the better they know our business, and the better they can respond to our wishes."* (Interview 19, translated by author)

At the start of a project, a new software services supplier is trusted with smaller scale projects, even when previous experience and skills are on-hand. During such new beginnings, preparation of the user specification document serves as a basis for partner analysis for automotive firms. It involves meetings in person, more frequently at the beginning and intermittently thereafter, which serve as occasions for exchange and clarification. As the project progresses, the user specifications document becomes more detailed and itemized. During this interactive process, automotive enterprises gauge the ability of suppliers and at the same time strive to instil their views on technical, commercial and esthetical problems and solutions in the service provider.

As such, this approach resembles the three phases of learning processes in business relationships as described by Håkansson and Johanson (Håkansson/Johanson 2001 pp. 2-6, Section 2.1.2). The introductory projects, the first of the three stages, serve as tests for willingness and ability to continue doing business together. Consequently, firms modify their process to lower transaction costs, which not only creates interdependencies, but also increases the value of the relationship for both sides. Ideally, this is accompanied by positive sum gains and shared outcomes for both sides and also increases the knowledge production capacity, which is influenced by the surrounding conditions (Brown/Duguid 1991 p. 48). The final phase includes repeated interactions and leads to the coordination of more long-term activities of both parties.

Similar to serving a risk-aversion function, these initial projects are also processes of cognitive and organizational pull, and an IT-manager at an OEM refers to them as "*trainings*"

(Interview 22, translated by author). At the same time, such projects also incubate social proximity between business partners. Following successful "trials", software services firms hope to win larger and longer-running contracts. These minor projects function as tests of skill in the specific context of the task and the customer, and are, at the same time, occasions for the establishment of customer-specific aspatial proximities. In a way, cognitive proximity appears to be constructed by clients in their suppliers with a certain degree of conscious decision, at least in certain cases.

Boschma writes "Social proximity is defined…in terms of socially embedded relations between agents at the micro-level. Relations between actors are socially embedded when they involve trust based on friendship, kinship and experience"[58] (Boschma 2005 p. 66, Section 2.1.3). During the interviews with automotive firms, the inter-personal dimension appeared to be a significant factor. Especially at the beginning of new projects with first-time partners, personal contact (*"to look in the eyes [of the other]"*) is sought to gauge whether trust-based relations can be established (Interviews 16 and 20). Perhaps even more so than for cognitive proximity, the building of social proximity requires personal interaction and shared experiences. Even for intra-firm relations, as an IT-expert in a local OEM declares, social proximity is in play:

> *"Communicating only through some technical medium or video-conferencing does not create such closeness…I notice this with my colleagues in [the other location of the OEM]. When I communicate with someone only through video-conferencing, I don't know if I will get what I request or whether he understands what I tell him."* (Interview 16, translated by author)

Social proximity eases relations as it allows for less formal and less restricted communication. As the same interviewee from the last quote put it, *"I can pick up the phone and ask a daft question [without discomfort]."* As such, social proximity removes some barriers to communication and supports the building of cognitive proximities by allowing for the exchange of tacit information between parties.

The definition Boschma offers for organizational proximity places the emphasis on "the rate of autonomy and the degree of control that can be exerted in organizational arrangements" and organizational arrangements refer to the relations within or between enterprises (Boschma 2005 p. 65). In terms of organizational proximity, the market for automotive-oriented software services resembles a collection of loosely coupled networks. Apart from certain

[58] In this sense, values, e.g. of an ethnic or religious kind, are not involved in this dimension.

software services firms owned by automotive enterprises (for instance GEDAS, whose majority shares belong to Bosch), most software firms are legally independent of automotive firms. However, as software services for automotive industry is a sub-segment in the overall software market and firms address smaller niches in this domain. Even when software firms reach a certain organizational size to address foreign markets, their number of clients remains structurally limited. It is also not uncommon for these niche firms to grow through their intense business relations with their customers, which actively participating in joint product-development activities.

Software functionalities are closely interwoven with the design and performance of internal and external processes of automotive firms and the software choices include significant and irreversible investments, not only in license costs, but also in know-how building. An example is the crash test simulation software: nearly each German OEM group works with a different software package and undertake substantial investments. It is therefore their interest and their wish to try to influence the further technical development of software. Here coordination mechanisms between both sides are much closer than that of an idealized on-the-spot market environment. The relations between automotive firms and these specialized software companies resemble a case of “quasi-integration” and display a mixture of market and embedded relations as mentioned by Uzzi (Section 2.1.2). The financial and organisational problems and limitations of software services providers can be extremely consequential for automotive firms. Therefore, larger automotive firms tend to work with larger software suppliers, which can react more flexibly to their demands and are often perceived to have higher survival chances than smaller ones.

One can speak of organizational interdependencies between automotive and software firms, but the power they wield are not comparable. Automotive firms have often a clear size advantage, which gives them a stronger hand in the negotiations, and they can afford to work simultaneously with competing software solutions. Although it is more costly, such an approach helps to maintain manoeuvring room and security in mission-critical applications. Such advantages provide automotive enterprises with an organizational, if not cognitive, distance over software suppliers. In terms of organizational adaptation, it is the smaller software firms that are driven to modify their ways to be able to work with larger automotive enterprises. Automotive supply chains are quasi-governed by OEMs and their working methods and processes function as templates for component and software suppliers. Therefore, it is the OEMs that define the “connecting principles” and codes of behaviour argued for by Loasby and Arrow (Section 2.1.3).

Previously in this section, Håkansson and Johanson's business relations notion was mentioned in relation to automotive firms' tendency to test new software services firms' capabilities with small-scale projects (2001 pp. 2-6). The authors suggest that the second step in business relations includes mutual modification of routines and processes between transacting parties, or in other words, the development of organizational proximities. As such, this requires the parties to adapt their processes as well. But the imbalance of size and power and the unwillingness of OEMs and large suppliers to change forces software services suppliers, which often have flatter organizational structures, to adapt more readily to their customers. As such, there is a hidden danger for software firms to be locked in excessive organizational proximity to their clients.

Things work differently with smaller automotive firms, which are claimed to be more flexible and adaptable. A regional expert, who manages a local network initiative on virtual reality technology, remarks on the decisions by automotive suppliers to implement virtual reality applications:

> *"One also has to mention that SMEs*[59] *are very flexible and … they do not have big hierarchies. We notice [in our activities] that once the boss, development manager or general manager decides [favourably], it will be implemented. In large enterprises, such decisions take months."* (Interview 4, translated by author)

The role played by formal and informal institutions was confirmed during the expert interviews. To begin with, formal institutions play a fundamental effect on demand behaviour in that they affect the strategic purchasing decisions. Namely, the preferences regarding the institutional environment coincidentally define the geographical borders of software supplier search of an automotive enterprise. This is reflected in the internal software services purchasing principles of a local OEM, who considers the following criteria (among others) before deciding on an off-shore services supplier:

- Recognition of intellectual property rights
- Adherence to non-disclosure agreements
- Legal security on contracts

Here, a legal assurance level comparable to Germany is sought in the outsourcing location. In other words, prior to an outsourcing decision, customers seek a degree of institutional proximity between locations. Absence of proximity as such causes either the failure of a

[59] SME: small and medium sized enterprises.

contact or limitations on the contents of cooperation. On the other hand, presence of such proximity helps a trust-based relation to develop, which eventually increases the knowledge-intensity of interactions.

Language issues and differences in working and career planning habits were mentioned by interviewees as barriers to knowledge-intensive projects over geographical distance. For instance, although English is the lingua franca of the business world, it is not the case that all employees of an enterprise are comfortable using it. As such, language limits the knowledge-intensity of the relations to a large extent. As the knowledge content becomes more sophisticated and tacit, persons find it difficult to express it in a non-mother tongue. Furthermore, for automotive-oriented software applications, the experts in non-IT departments are of crucial importance in that they contain the tacit know-how in their fields of expertise. However, these persons do not always command the necessary skills in English, which limits their involvement in software projects with foreign software firms or foreclose some software firms out of projects.

> *"In our department, people do understand English but we always have to engage the [internal] departments [that work largely on the automotive-engineering side] which are specialists in their areas. You cannot expect all of them to speak English. This means there is always a certain distance. Or less willingness. This means, when an English-speaking provider comes over, these colleagues are unwilling to join. Consequently, some offers are rejected not because their quality leaves us wanting, but due to expected difficulties in cooperation."* (Interview 16, translated by author)

This expert remarks that a Japanese software firm that provides software applications and services in the CAD/CAE field faced similar problems when it operated through its own offices with employees from Japan. After failing to penetrate the German market largely because of communication-related difficulties, the firm decided to contract a leading German software solutions and services provider to push its products and services in Germany.

The challenges involved in operating in these locations, such as legal issues, difficulty of creating employee loyalty, cultural and language differences require a level of management focus that automotive firms cannot afford (Rao 2004). The working habits and loyalty to employers (or lack thereof) in India have been mentioned by different interviewees from both the automotive and software side (Interview 15 and 17). Despite the Indian employees' skills in implementation, their unwillingness to communicate negative issues, allegedly a cultural characteristic, causes complications. For instance, despite noticing mistakes in a requirements document, an Indian employee would abstain from communicating this and continue to complete the task, ending up with an unwanted piece of software. Larger automotive firms respond to this challenge by allocating employees from Germany to coordinate operations and handle communication, or in other words to act as aspatial proximity buffers for their firms. The function of large services suppliers in the enterprise software field, like IBM and T-Systems, is similar in the sense that they shield Western European customers from the negative effects of institutional incompatibilities.

An important function of institutional proximity dimension appears to be its key-role in allowing other forms of proximity to come into being. Institutional proximity in the form of a shared language and a basis of trust based on legal compatibility of locations provide the ground on which social, cognitive and organisational proximities develop. Indeed, it is quite clear that if institutional proximity fails to develop, knowledge-producing business relations may fail to exist. Therefore institutional proximity defines the geographical borders of KIPS supply-demand relations.

Boschma states that the interplay between cognitive proximity and distance accommodates and stimulates learning between two entities. This notion can be summarized by the following quote from Noteboom: “a trade-off needs to be made between cognitive distance, for the sake of novelty, and cognitive proximity, for the sake of efficient absorption. Information is useless if it is not new, but it is also useless if it is so new that it cannot be understood” (2000 p. 153 in Boschma 2005 p. 64). This notion applies for relations between different sectors as well. For automotive and software services a certain minimum common knowledge basis in the automotive-related application field and an IT-related know-how advantage by software firms over their customers are necessary for continued relations. The common knowledge basis is built largely by application-specific and shared experiences, which allow the software firm to speak “the same language” as their customers. This has been discussed in more detailed in the preceding paragraphs. The cognitive distance between automotive and software firms is partly maintained by the extensive technical and social division of labour among them. As automotive manufacturers transform themselves into system integrators (Section 2.3.3), software development tasks are transferred to specialized enterprises. Software applications and services are sophisticated repositories of knowledge, whose mastery places software suppliers away from their clients.

4.6.3. Spatial proximity for automotive firms

Due to the capital-intensive nature of automotive supply chains, a firm's performance is largely affected by the pace with which it transforms ideas into processes, goods and services. Due to this reason, economies of speed[60] are a helpful notion to understand the behaviour of OEMs and Tier-I suppliers, which vanguard the industry practices to a large extent. While economies of scale and scope remain important as ever, in the globalized automotive industry of today it is the skill and efficiency with which operations are coordinated - or economies of speed - that separate successful enterprises from others. Issues about costs and the search for low-cost-base locations do not undermine the importance of speed economies but simply make them more challenging to achieve. The challenge today is the speed with which an enterprise acquires lacking know-how, rather than the fact that it does acquire it.

Software tools allow the efficient coordination of interdependent activities in and across enterprises, even in geographically distributed settings and they are often indispensible for the operationalization of strategies that aim speed economies. (Chandler in McGraw 1988 pp. 401-403). At the same time, despite their central importance, software applications are only means to an end for automotive firms, and strategic purchasing decisions regarding software are taken in consideration to the overall business cases associated process environments, and the contribution of software application in creating competitive advantage in the core activities. In services, the cost of a project is heavily dependent on the wages of those involved and under the long shadow of costs and innovation pressures, automotive firms do seek locational advantages. Besides, German automotive firms have established component supply relations with lower-cost locations in new EU member states. With this background, the central question would be "under what conditions does an automotive firm seek geographical proximity to its software suppliers?"[61]

The software-intensive automotive development and automotive-oriented software services fields, which in fact complement each other, are practically formed of so-called communities of practice, which incorporate strong cognitive – in certain cases also social – proximities between practitioners (Gertler 2003 p. 86). Therefore, it is conceivable that a supplier from the same area of specialisation can possess the minimum required level of proximities to start

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[60] Economies of speed were explained previously in Section 2.3.3 within the context of the Toyotaist mode of organization.

[61] It is necessary to remark that is "geographical proximity" has a pragmatic meaning for automotive firms. In practical terms, the ability to book a meeting in at short notice and to be able to carry it out during the course of a day appears to suffice automotive firms in many cases as geographical proximity (Interviews 3, 10, 12, 16, 23). As such, proximity has a functional meaning which corresponds to a travel time up to 2 hours (Section 2.1.4).

a knowledge-producing relation, even if it is located elsewhere in Germany or Europe. It must also be mentioned that in the age of cheap air travel and extremely fast trains, temporary proximity is a viable alternative to setting up shop near customers permanently. As long as individuals belong to the same community of practice, they can theoretically deal with knowledge-creation processes over geographical distances.

If the knowledge involved in a particular project can be expressed in standard terminology and processes or, in other words, can be codified, then such a relation does not necessitate permanent co-location and can work through temporary proximity. The case of a leading software specialist working for a prominent Stuttgart-located CATIA solution provider is a fine example. Of Dutch nationality and still living in the Netherlands, this person speaks fluent German. He undertakes and leads development activities for module development in a CATIA environment and maintains contact with clients in Stuttgart through temporary visits and ICT-tools. His case exemplifies how temporary proximity can suffice when effective aspatial proximities are established in a community of practice.

However, the codifiability and change dynamics of knowledge content or, in other words, the cognitive dynamics of the processes appear to be important arbiters of spatial proximity requirements. In the software services for automotive industry context, codifiability finds its expression in shared standards of software engineering (e.g. languages, interfaces, technical communication protocols…) and process that are matched between organizations and locations. Where such standardized and accordant processes exist, they provide a relatively stable and shared basis for cognitive proximity for both parties. Where knowledge is continuously re-combined, re-defined and freshly created in short periods of time, its fluidity increases and codified exchanges fail to keep up with the pace of persons who create and interpret the knowledge. Thus, tacit exchanges become necessary to prevent knowledge gaps between parties and persons are compelled to engage in more frequent F2F exchanges.

Time pressure or the automotive firms’ search for economies of speed play an important role in these processes. As firms seek to maximize time out of processes to make them leaner, employees seek efficiency in communication. While IT-tools provide some very effective ways of information transfer, F2F interaction is still the most efficient for processes with dynamic and tacit knowledge content. The required frequency of such personal meetings affects the transaction costs and the pace of the knowledge creation process, hence also the decision between temporary and permanent spatial proximity. As such, the current findings are in-line with the arguments from literature that the significance of geographical proximity increases with the knowledge complexity and socio-spatial contexts (Morgan 2004 p. 8).

On a different note, in the pre-development phase, where time pressure is relatively low as compared to product-development processes, the novelty of knowledge outweighs other criteria and relations with spatially-distanced KIPS firms are more readily accepted by automotive customers. Illeris reports similar client behaviour regarding highly specialized consulting services (1996 p. 197). A regional automotive expert, who retired very recently after spending terms at managerial level in research-oriented departments of a large supplier headquartered in Stuttgart remarks:

> *"I did a lot of pre-development and new development tasks. On the research side. There the distance played no role at all. We were simply looking for business partners around the world that were good. But in day-to-day and operative business, it is also crucial to have firms around with whom one can sit at a table and communicate without effort."* (Interview 8, translated by author)

A far-reaching example of how a knowledge-intensive business relation can function in a spatially-distanced fashion is found in the previously mentioned dealer management software domain. Although they are crucial components of a car brand in that they co-define the customer experience at the retail level, technologically speaking, these applications are less cutting-edge than most software tools deployed in vehicle development. Indeed, during the expert interview, an IT-manager at a local OEM jokingly remarked *"In principle, what we are talking about is [software] programs that write invoices"* (Interview 29, translated by author). The version used by the OEMs dealer is a customized version of a multi-platform/multi-language dealer management software package that incorporates specific interfaces and pre-defined process structures; however the basic technology behind it remains untouched. The on-going development of the software package is carried out solely by the software producer itself. This company is based in UK, but the development team is located in Netherlands, which is the address for German OEM's change requests. The interviewee states that it had taken some time to settle the workflows between locations and the shared terminology among teams involved, but since these had been established, processes have been working satisfactorily. He also added that the development work does not involve drastic change dynamics or the kind of cognitive dynamism involved in in-product software development.

Yet another special case is presented by software-intensive engineering services. These services are closely linked with vehicle development and consist of the outsourcing of development tasks by OEMs and suppliers (Section 2.3.3). While some of these firms offer rare know-how in specialized areas, engineering services is – to a large extent – a domain of capacity subcontracting (Holmes 1986 pp. 85-86) and in Germany these firms are called the "extended-workbench" ("Verlängerte Werkbank") of an enterprise. Engineering services firms are explicitly asked to locate in the vicinity of OEM development locations with "vicinity" meaning the possibility to be in the customer's premises at short notice in a couple of hours. Once again, the reason for putting such emphasis on geographical proximity appears to be a result of the cognitive dynamics of the development activity e.g. live interfaces to other teams' work, frequent changes, moving project milestones and specific know-how (for instance on light materials, which is developed partly in a "learning-by-doing" manner by the customer and the services supplier). However, social proximity also rises as an important criterion which is not surprising when one considers the intensity of cooperation between persons.

4.7. The dimensions of proximity for KIPS firms

Typical of KIBS firms, automotive-oriented software services firms provide the information or service products that stimulate their customers' knowledge-production processes (Section 2.2.5). Their services are configured for an industry totally unrelated to their own and as such these firms are highly dependent on the knowledge they can gather on their clients' products and processes. Besides, as is often the case with knowledge-intensive business services, the distribution of information in the market is highly asymmetrical between service providers (Larsen 2000 p. 149). This knowledge is in constant flux as the features and diversity of motor vehicles change rapidly and the automotive sector and individual firms go through seemingly incessant structural transformations (Section 2.3.3). Hence, the knowledge on customers and the market is a constantly moving target for software enterprises, which are compelled to keep in frequent contact with their customers. In this context, the proximity to customers, both in spatial and aspatial forms, can play a crucial role for these software enterprises for their competitiveness, if not for their survival.

As in other innovative activities, the creation or ongoing development of software products or services is associated with irreversible investments by software services firms. The efficiency of these investments is closely related to software firms' knowledge of automotive industry structures and processes (Sec. 2.1.2). The nature of these software applications and the specificity of their use demand a focused communication between the parties, which more often than not occurs during projects. The dominance of vertical relations suggests the considerable importance of traded-dependencies in the case of software firms. This feedback from customers provides the technical and commercial orientation that defines the opportunities and constraints for the creation and evolution of software products and services. Especially the software firms that develop niche products are attentive to customer feedback, as they have to align themselves to very specific implementation areas. The managing director of a smaller software firm remarks about their behaviour on customer feedback:

> *"We seek customer feedback aggressively, in fact. We have just completed a usability study together with our customers. This means we have a product idea, with which we ultimately believe we can create an interesting business case for ourselves. Then we conducted surveys and usability tests together with our customers in order to learn their opinion. For us, it is very important that we basically develop our product innovations in dialogue with customers. Because only then can we be sure that we are not developing things for the trash-can. That is something we simply cannot afford to do."* (Interview 13, translated by author)

In order to be able to process their direct and indirect signals, software firms need to establish cognitive proximities with their customers. Cognitive proximity comprises the understanding of the industry, of the specific sub-domain and of the processes used by the customers together with a mastery of the specific technical terminology. As such, components of cognitive proximity to customers are not readily available in the market and have a strong tacit component (Grimshaw/Miozzo 2006 p. 1253). Cognitive proximity enables software firms to comprehend and process customer requests for new features and equips them with the alertness to pick up latent needs of their customers or of the market.

Knowledge of the industry and of specific sub-segments is partly derived through industry specific publications and through the gatherings of dedicated communities of practice (Section 2.1.4). Branch and segment specific trade fairs, conferences and symposia provide occasions for such events, where specialists meet and exchange the latest news and knowledge. However, process know-how and terminology can be transaction specific, especially when software users include non-IT departments of an enterprise, who are in return specialists in their own niches. As mentioned before in Section 4.6.2, automotive firms explicitly expect software suppliers to be efficient in such a specific "language", in order to be able to comprehend the problem definitions and requests facing them. It can argued that the absorptive capacity of a software enterprise increases along with its fluency in that "language", called *"the smell of steel"* (Interview 26, translated by author) by some software firms (Knoben/Oerlemans 2006 p. 77), as it enables the identification and comprehension of tacit and explicit customer knowledge (Boschma 2005 p. 63).

This specialist terminology is a codified expression or externalisation of tacit knowledge, but simultaneously it is a representation of how the comprehension of codified knowledge is closely linked to the tacit background (Nonaka 1994 p. 19). The build-up of such a dynamic and specific mixture of knowledge occurs through frequent personal contacts. The use of crash-test simulation software is an example, where the software supplier, software experts of the OEM and the specialist departments build such a language through interaction.

> *"We have many employees that work on the premises of the [OEM]. Their daily exchanges with design engineers that do not speak the "DYNA language" are the order of the day…and in related team meetings, where design engineers and the simulation engineers [who actually know the software and can speak the DYNA language] attend, there one can learn a lot."* (Interview 27, translated by author)

What this quote additionally suggests is that learning-by-doing is part of daily work during the intensive project activities between automotive and software enterprises. Secondly, software firms are also expected to develop knowledge of the customer process flows and sequences. This knowledge has tacit elements and it changes dynamically in time as customers' processes evolve and transform. The tacit dimension is even more pronounced in cases where the software application has interfaces to more than one function or process on the customer side. As such, especially for services enterprises, cognitive proximities with customers are established at the employee level through experience and interaction. This finding corresponds with Nonaka and Takeuchi's argument that tacit knowledge is contained in individuals (1995 p. 225). As was discussed previously in Section 4.6.2, the cognitive distance the software firms needs to maintain over their customers is induced by the technical and social division of labour in the market. The cognitive and organizational agility of smaller software enterprises as compared to larger automotive firms is also to their advantage in terms of gaining expertise in new technologies.

The social dimension of business relations contributes to the knowledge-production potential of interactive processes (Willcocks et al. 2004 p. 8). The interviews with software enterprises revealed closer relation between the cognitive and social proximities than for automotive enterprises. As mentioned before, cognitive proximity to customers is not an asset that is available on the market and it comprises strong tacit components, therefore establishing interpersonal relations with clients appears to be crucial for software firms to establish functioning business relations (Grimshaw/Miozzo 2006 p. 1253). In the software services for automotive industry domain, knowledge is asymmetrical and up-to-date knowledge is scarce, hence in such an environment, know-who gains in importance (Lundvall/Johnson 1994 p. 28). At the beginning of new projects or sales processes, software enterprises require knowledge relating to the exact needs of the customer, which contains explicit and tacit elements.

While the explicit portion may be openly available, the tacit part can only be attained through personal interaction. The element of trust realized by the social proximity to the customer stimulates more open dialogue and hence a more vivid exchange of tacit knowledge between parties. Indeed, in software services segments where unique selling prepositions are more difficult to establish, social proximity becomes a competitive advantage. Other selection criteria being comparable, the persons who purchase services for automotive enterprises prefer to work with firms with which they entertain trust-based relations and easier social contacts. While the skills of the software firm are the basis of long-lasting relations, the trust based on previous experiences acts as the decisive factor.

F2F interaction during sales discussions is a means of gathering customer-specific information and comprehensive problem definitions. An in-product software development manager at a regional supplier that develops complex in-car entertainment systems stated:

> *"It is important to understand what the customer wants, not what he says."* (Interview 18, translated by author)

For this, he suggested, one needs personal contacts and geographical proximity. F2F interaction also offers a more rapid means of communication for complex topics, as it allows the clearance of a chain of interlinked questions all at once. To the question as to how the location of a customer affects their relations with them, an interviewee at an in-product software development tools supplier responds:

> *"It always depends on the process. In sales, it is absolutely necessary to be where the customers are. Negotiations are necessary and in order to win a contract, one needs solutions agreed by both sides. This does not work through the Internet. Later, during development, a lot of things are fixed on paper. There one has specifications, along which the development takes place. Therefore it does not make a difference where you are, here, in Japan or in US. Then there is a short period of time when the solution is implemented on the customer's site. During this period, we are at the customers' premises to carry out the necessary project meetings. Telephone and*

videoconferencing are sufficient in many cases during the development phase." (Interview 2, translated by author)

The institutional proximity or, in other words, having a common language, established habits and sharing formal and informal rules appear to play a functional role in how the activities of software firms develop geographically as they grow. For one, institutional proximity has a stimulating effect on the establishment of social proximities, as it provides the persons with a common medium of communication and shared codes of social conduct. Without this background, claimed one interviewee, *"the human component would be missing"* (Interview 26, translated by author).

Secondly, despite the convergence of regulations in the global business area and even regulatory homogenisation in the European Union, formal institutions still have differences across borders, which affect the commercial and legal processes software has to comply with. For software applications that address inter-firm business relations, legal frameworks affect the extent to which data exchanges can take place and processes can be connected.

The discussion of organizational proximity for software enterprises is a continuation of the arguments presented in Section 4.6, where the same topic was considered for automotive firms. As described in the afore-mentioned section, the automotive-oriented software services market is organized from loosely coupled networks of enterprises, where certain degrees of mutual interdependencies exist. For automotive firms some of the software applications serve as cognitive platforms within and across their enterprises, where intensive sector-specific knowledge exchange takes place. The CAE software CATIA is an example for such a software platform. The financial and human investments in these software platforms are understandably high and automotive firms prefer to use them for long periods. The resultant long-lasting relations can take on a quasi-integrated form (Granovetter 1985 p. 497), where the customer has influence on the direction of software development and customers are not very happy to share this with others. A manager at a software enterprise suggested that German automotive firms prefer to work with their compatriots because:

"With German automotive manufacturers, a German location is an advantage. [German OEMs] simply say: "It is preferable for us to work with a German [software] enterprise, where we simply have a closer contact. If it were an American software producer, which would get [in addition to ours] a contract from the

American Government, the software could be developed in a direction without us being able to have any influence[62]*."* (Interview 13, translated by author)

For instances where automotive firms enjoy a favourable power imbalance, their behaviour regarding the organisational proximity varies depending on the enterprise or divisional strategies or plainly on persons. According to the interviewed software enterprises, the same automotive firm can exhibit very different behaviours. While some departments of a local OEM agree to co-finance the development of new software applications and place no restrictions on their further sales to other automotive firms, other representatives of the same enterprise insist that the software provider covers unforeseen development costs, which would be caused by the customer's own miscalculations and mismanagement. In order to avoid dependence and too close organizational proximity to too few customers, software firms try to expand their customer basis by seeking entry to new geographical markets and application segments (sometimes outside the automotive industry). However, such a strategy appears to be bounded by the organizational capacity and size of the individual enterprises.

Similar to the case of automotive firms, the cognitive dynamics involved in the creation, implementation, use and maintenance of a software solution appear to have a great influence on how software firms approach geographical distance to customers. Again, beside the tacitness and codifiability of knowledge involved in individual processes, the time pressure on the processes plays a decisive role as well. For devising software solutions and services, where speciality knowledge from experts from both sides is required, the necessary frequency of interaction is high and time lines are short, the software firms too find it difficult to replace geographical proximity and the agility of F2F with ICT communication tools.

The software firms confirmed the assertion that their knowledge-creation processes have a strong interactive dimension and automotive firms are important drivers of their innovativeness. However, the role of geographical proximity for communication efficiency appears to vary across segments. The owner-manager of a software enterprise, whose firm specializes in software tools for in-product software development, was certain about the benefits of geographical proximity to customers. He states that business relations do function over distance, especially with the help of ICT tools, but that his firm achieves a higher turnover with nearby customers who also provide the majority of product improvement suggestions. His testimony gives support to the argument that spatial proximity eases

[62] This quote also brings to mind the organizational proximity discussion in Section 3.2.8, where the automotive firms' willingness to influence their software suppliers was mentioned.

communication across enterprises and accommodates the maintenance of cognitive proximities (Section 2.1.4). The same interviewee declares:

> *"When something about our product is not quite right but not too disturbing, a customer probably would not communicate this by email. But if one is locally present, these things can easily be communicated and solved."* (Interview 1, translated by author)

In another example, a software application that simulates special situations in airbag deployment was developed by a local software firm in close interaction with the experts of a local OEM. The special cases to be tested involved situations where the front passenger sits or is placed out of the ideal sitting position and required the special experience of crash-testing experts of the OEM. A manager from this software enterprise comments on this experience and how being spatially close to customers accelerates the solutions thus improving their status in customers' eyes:

> *"Development activity would surely work without local presence but we would loose a lot of our strengths and advantages…Or at least it would lead to slower growth of orders [from the customer]…For instance, what I mentioned before, the "out of position" analysis, it was really important to have exchanges with respective specialists from [the OEM] and almost on a daily basis so that we also built up personal relations. It was also important that what requirements they had were handled with high priority…somebody [from the OEM] would come over, would give the command "build this [function] in" and afterwards it worked [for him]. This was very important. When you manage this, you are the champion. When you come over with big words, promise things and don't deliver, you're not welcome anymore. With a pressure situation like this…if a problem is not solved over the weekend, [the customer] wants to know exactly why."* (Interview 27, translated by author)

In comparison to these firms, another enterprise that provides on-demand e-procurement solutions to automotive and other sectors experiences matters differently. The software services offered by this second firm are clearly less automotive-oriented, although it has numerous customers from the supplier realm. To be technically more precise, this service is based on a centrally installed and maintained package of software solutions that is utilized remotely by different customers primarily for purchasing management purposes. The main challenge for customer implementation of this solution is to adapt the software and the internal processes of the customers with each other.

The interviewee declares that customers are the main source of product developments and adds that representatives of the firm, who act as intermediaries between end-users and development teams, visit their customers about every month. Besides, the firm reaches out to enterprises which display typical characteristics of a sector and organize product improvement working groups with them. In short, this is a firm which lives on its knowledge of its customers and which consciously seeks their feedback. The firm is established in Stuttgart region, but the majority of customers are distributed around German-speaking countries, with the North German states of North Rhine-Westphalia and Lower Saxony being the lead locations. The firm does have international customers, but contacts with these clients are mostly established through their branch or head offices located in Germany. The interviewee also states that compared to language, spatial distance to customers plays a negligible role and that clients in German-speaking countries are significantly more active than others in their feedback. This suggests that regular meetings with customers, or in other words temporary spatial proximity, supported by ICT tools, can accommodate knowledge exchange and production between transacting parties as long as necessary aspatial proximities are in place. The same interviewee states:

> *"There have been firms that consciously chose us [out of competition] because of our geographical proximity…true, during [such a] project one is more available than when one is located further away. We had more personal discussions meetings but it did not result in a more successful project."* (Interview 26, translated by author)

During the pre-production or pre-process phase, having shared interest and being in possession of rare knowledge assets can be sufficient for knowledge-production and mutual learning to proliferate despite geographical separation. Here persons are close to each other not only because they interact, but because they possess rare pieces of associated knowledge, which they wish to augment in interaction with other members of the community of practice (Torre/Rallet 2005 pp. 49-50, Section 2.1.3). An example thereof is given by the leader of the competence centre for virtual reality software at a Stuttgart located research organization. Among other things, this competence centre develops research-oriented software applications for industry in the virtual reality domain and has close working links with the automotive industry. In response to a question about how customers contribute to their development activities, he remarks:

> *"[The customers] bring a lot in terms of maturity. What we develop is rather research prototypes. When they are implemented by customers, they reach a [level of] product-*

maturity…If we had no customers, [our products] would never reach the maturity they now have. This definitely depends on proximity but it does not have to be geographical. I mean more in a common work context. It can by all means be that in a certain project structure, which we have in international cooperative projects, one gets together [with experts] who are not located nearby, but somewhere in Europe…Proximity does not mean that the firms are located around the corner but it means that one meets frequently and has a [common] motive." (Interview 10, translated by author)

All four kinds of knowledge stated by Johnson et al. are crucial for KIPS firms' relations with their customers: know-how, know-why, know-what and know-who (Johnson et al. 2002 pp. 249-251). Know-who is very crucial for software firms, as it allows them to build social proximities with the right persons and social proximity itself plays a pronounced role in that it provides access to customer-specific knowledge. By developing and maintaining social proximities with the "right" persons in their customer enterprises, software firms create and protect the flow of crucial knowledge to align their products and services (Lundvall/Johnson 1994 p. 28). Especially with large customers like Daimler, which – according to an interviewee – is *"a marketplace in itself"* for smaller software services firms (Interview 24), social proximity becomes even more crucial. Institutional proximities play their part by closely affecting the establishment of social proximities between parties. As for organizational proximity, network structures persist among automotive and software firms, but the power relations are imbalanced in most cases. It is as if the aspatial proximities formed the scaffolding with which knowledge-producing relations with customers are constructed.

4.8. Lead firms as demanding local customers

Porter claims that local demand conditions would create incentives and market-foretelling insights for co-located enterprises (Porter 1998a pp. 87-89, Section 2.2.4). The novel type of demand by local customers can stimulate firms to specialize in certain segments, which may develop to have a global size. Some of the more competitive and innovative OEMs and suppliers of the European automotive industry have their home-base activities in Stuttgart cluster (Section 2.2.2). These firms have a track-record of pioneering and market leading high-quality products and they continue to invest heavily in R&D. Among them, firms like Daimler, Porsche and Bosch act as the lead firms of Stuttgart region due to their purchasing power, high employment and dense localized supply relations. In the following pages, the influence of these lead firms in the context of knowledge-producing relations will be presented through three examples from Stuttgart region.

The first example is a globally-renowned supplier of tools, software components and engineering services for the networking of on-board electronics and embedded-systems development. Its headquarters and R&D operations are located in Stuttgart region, where the firm employs over 400 employees. While it continues to expand its global network of subsidiaries and distributors, its regional operations are also growing with new investments. The story of this enterprise is closely linked with Bosch, which was among the early developers of vehicle electronics. These early electronic systems functioned in an un-networked fashion on discrete on-board units. Three ex-Bosch Group employees, who foresaw the necessity for on-board networks to connect these discrete systems in motor vehicles, founded the firm in 1988 and took on the development of the very early software tools and components in this field. The development was carried out in close cooperation with Bosch and the very early customer implementations were realised within the cluster at Daimler. As the firm grew, its customer portfolio expanded with Tier-I suppliers and OEMs and interestingly Bosch is no longer the biggest customer account. Today, the firm consciously tries to avoid having a single customer with more than 20% turn-over share.

The second and third examples involve two different firms that develop virtual reality software applications and whose early histories share similarities. In spite of the high development costs in early stages, automotive industry, including Stuttgart-located OEMs, has been one of the early adapters of virtual reality technology. Daimler continues to invest heavily in this technology and Porsche, besides its internal use of it, is also supporting the regional virtual reality competence centre in Fellbach in order to accelerate the diffusion of this knowledge across its supplier networks. In recent years, suppliers have started using this technology more intensively, partly due to requests from OEMs.

The first of these two software firms specializes on the interactive visualisation of simulation data in 3D. The initial development was carried out in a research project at the University of Stuttgart, which was strongly motivated by the aircraft manufacturer Airbus. However, the commercialisation of the software was driven by the local OEMs in Stuttgart region and they became the first two commercial customers. They had originally been involved in the development project, but demanded additional usability, stability and scalability levels combined with complementary services such as documentation. All of which would be provided by an enterprise software services firm rather than university research departments and the commercialisation phase followed. Today, the firms continues to cooperate closely with academia, but since then it has added not only other automotive firms and but also other sectors to its portfolio.

The second enterprise offers a set of modular tools that assist the visualisation of vehicle components during the development phase. The initial software development took place at the Fraunhofer Institute and then commercialization phase followed in a spin-off company in year 2000. Links with the automotive industry were strong from early stages, and although the core of the software application has been completely re-created since then, automotive firms continue to make up 70% of the revenue. A local OEM played an important role in the commercialisation process with its commercial and technical support and since then it has added this enterprise to its list of strategic software suppliers. As it grew, this software firm sought to win automotive customers from outside the region and has managed to develop an international portfolio. As the revenue model depends on services revenue rather than licence fees, the role of the local OEM in balance sheet numbers has diminished in time. However, it continues to be the most active customer among other OEMs.

These three cases display the role of lead enterprises as demanding local customers and how they go beyond being only consumers of a pioneering technology, but also become co-developers of it. The strong technical knowledge of lead firms not only increases the effectiveness of their communication with their software suppliers, but also enables them to be involved as knowledge co-producers that extend the expertise of service suppliers (Miles 1996 p. 252, Grimshaw/Miozzo 2006 p. 1247). In these examples, they contributed the early knowledge capital of the software firms and still continue to collaborate actively in the further knowledge-production. At the same time, local lead firms anticipated the demand elsewhere when they adapted these technologies[63].

In developed economies and especially for the development and production of complex products such as high-end automobiles, the core knowledge-production processes resists codification and geographical dispersion (Wolfe/Gertler 2004 p. 1078). This phenomenon creates networks of knowledge-production around the lead firms in clusters, where large enterprises act like central nodes. The automotive cluster in Stuttgart region is almost a text-

[63] Porsche is also a member of the previously mentioned regional network on virtual reality technology, VDC. According to declarations from this network's manager, Porsche is using VDC consciously to accelerate the diffusion of virtual reality technology across its local supplier base.

book example, where highly technology-oriented[64] and demanding customers create a momentum of knowledge-production and innovative stimulation. This stimulation is embedded in the relations between business partners and, as such, is not necessarily bounded by spatiality. However, the afore-mentioned resistance to codification and the cognitive complexity of the more complex relations lead to their geographical concentration.

In addition to the supporting evidence for Porter's arguments on demanding local customers, the interviews with software enterprises showed the reluctance of suppliers to over-dependence or, in other words, to excessive organizational proximity. This intention seems to be the stimulant for firms to expand their geographical reach as they grow and augment additional knowledge, capacities and contacts (Hayter 1997 pp. 237-238). As the firms evolve and expand, they seek to distribute their business over different customers, a strategy which often requires winning customers located elsewhere. As firms build global contacts, the knowledge creation effects and stimulants are distributed across the customer portfolio and the role of demanding local customers can be expected to recede.

4.9. Aspatial proximities and spatiality of tertiarisation

Before proceeding further with arguments relating to structural change, it is necessary to stress the type of structural change that Stuttgart region and its automotive cluster represent. To begin with, despite globalization and competitive pressures, neither is currently going through a crisis. A sign for this is the low regional unemployment, which has reached as low as 3.9% as of June 2008[65]. The automotive cluster has experienced relatively stable employment numbers and an increasing turnover in recent years (Section 4.3). Several world-leading OEMs and suppliers, which are focused on high-quality and technology-oriented products, have their higher-level management and R&D functions in Stuttgart region. Although production still plays an important role, the cluster level functional tertiarisation is significantly high at 54%. The regional private and public research infrastructure and the rate of R&D investment levels are exemplary.

As previously mentioned, software services for automotive industry is a form of producer (or intermediate) services activity that is dependant on industrial customers (Section 4.4). These services can be considered in the context of the transformation automotive products and processes are experiencing as part of the late fourth and early fifth Kondratieff waves. As discussed in Section 2.3.1, a new wave of technology that evolved from previous

[64] See the patent production of the large automotive firms in Stuttgart Region in Section 3.2.3.

[65] "Niedrigste Arbeitslosigkeit seit 17 Jahren im Südwesten", Stuttgarter Zeitung 2 July 2008

technological revolutions has different influences on existing sectors. While some of the older technologies have been replaced by new ones, others have been transformed by the possibilities offered by the new wave to perform at a higher level. Likewise software related technologies transform the product and processes in automotive industry. While automotive products are turning into electro-mechanical systems on wheels, software services firms are becoming crucial members of the automotive value chains.

The relations between software services and automotive firms are organized in networks that are largely dominated by OEMs and Tier-I level suppliers. These networks not only accommodate business relations, but are at the same time the loci of proximity management for actors and firms. The OEMs, which are positioned at the very end of the automotive supply chain, manage to influence the technical, organizational and geographical characteristics of the development and manufacturing processes in these networks. The central nodes of the automotive networks are therefore often occupied by OEMs, most of which have historical connections to a limited number of locations. Although they operate globally, these locations remain crucial for the governance of KIPS networks. For instance, Stuttgart region, Wolfsburg and Munich in Germany and the Île-de-France region of France posses such historically developed functions for OEMs. For software services for automotive industry as well as other KIPS, these locations are the main markets and spatial agglomeration nodes.

The decision behaviour that governs entry to these locally anchored but globalized automotive networks is again defined by automotive enterprises and on the surface, these firms take decisions on the basis of costs, quality and time. Although purchasing decisions at the firm level appear to be an optimizing act along these three dimensions, there are, in practice, other influences to note. In broad terms, these can be grouped into three areas: firm strategy, technologies and processes, and social networks. Firm strategy defines the framework that confines the limits of options in terms of technology, cost and geographical reach. In their turn, the codifiability and customer-specificity of technologies and processes largely affect the technical possibilities of geographical distribution for traded and untraded services activities (Sections 4.6 and 4.7). Last but not least, the social relations between actors and social networks do appear to influence the decisions taken by automotive enterprises. Although shared education or work places are important, these social relations are not necessarily friendship-based, but depend mainly on perceptions of trust, which often relates to past joint experiences.

KIPS are almost always customized for the characteristics and needs of clients. This requires gathering knowledge that is not available on the market, but only through contacts with the organization of the customer firms. Therefore, in practical terms, in order to gain access to these networks, software services firms have to build aspatial proximities with the key departments and persons in automotive enterprises. Building social proximity is important in the early phase of a new customer-supplier relationship. However, elements of cognitive proximity are also simultaneously at play, because the establishment of a trust-relationship has a higher likelihood when a software services firm displays a certain level of know-how and expertise in an application area (Interviews 16, 19, 20, 22, and 23). Joint projects function as mediums of learning-by-doing for software suppliers, in which they develop a clearer and sometimes inside picture of their customers' operations and requirements (Section 4.7). During this process, software firms, which are often smaller in size compared to OEMs and Tier-I suppliers, adopt their processes for their customers to establish organizational proximities as well.

However, the positions of automotive and software firms do not remain static in time along cognitive, social and organizational proximity dimensions. The cognitive side of processes appears to be the most dynamic as a competitive business environment stimulates constant change in customers' knowledge bases and operational processes. Besides, for a given OEM, vehicle models do not phase-in and -out simultaneously. There are always new models in development with a continuous focus on process improvement. For suppliers, the situation is no different, as a Tier-I supplier works on multiple models for various different OEMs at a given time. In short, knowledge-production is a non-stop process and the reference points against which knowledge-intensive services firms must constantly align their offering to these changes and to the future plans of customers.

Due to organizational transformations and staff movements, the changes in social and organizational proximities are arguably more discontinuous than for cognitive proximity. Considering the close relation between social and cognitive proximities, software firms try to maintain social contacts with their clients through F2F contact. As for institutional proximity, here change is relatively slow compared to other dimensions. However, as was mentioned in Section 4.6.2, institutional proximity plays more of a gate-keeper role and its absence often prevents knowledge-producing relations from starting.

Given this background, F2F interaction is vital for software services firms to manage aspatial proximities making it irreplaceable. The main decision criterion for permanent spatial proximity to customers is the frequency of F2F interaction required by the exchange processes. This frequency is largely determined by the tacitness of the knowledge content and coordination characteristics of these processes. The coordination of the processes is closely linked to two parameters: time pressure on the project or process that the software services are associated with, and the number of interfaces to other projects and knowledge-production processes. For complex problems that involve multiple inter-connected processes and unpredictability, codified communication proves ineffective when compared to F2F interaction. For cases with less time pressure, a services supplier can manage to handle its relations with customers through a mix of ICT tools and temporary proximity. However, as the allocated time for processes shortens, permanent proximity to customer locations becomes necessary for service suppliers in order to maintain aspatial proximities, reduce transaction costs and increase process efficiencies. Such arguments related to transaction costs and their effect as agglomeration drivers are also stated elsewhere in literature (Illeris 1996 p. 197, Storper 1997 p. 9).

For a given new enterprise, the choice of an initial settlement depends on other factors as well: agglomeration and urbanisation effects, personal histories and networks. As the firm advances, it either seeks partnerships with firms from other automotive locations, or opens up branch offices. Therefore the growth around competitive and knowledge intensive automotive clusters spreads. For software firms, the first location of settlement tends to maintain the lead in internal knowledge-production for a software firm, mainly due to the extensive infrastructure that establishes itself in time.

The agglomerated effect of these micro-level requirements to create and maintain aspatial proximities leads automotive-oriented software services firms to spatially agglomerate in and around existing automotive clusters. As such, these findings support the argument that in developed economies and especially for the development and production of complex products, core knowledge production processes resist codification and geographical dispersion (Wolfe/Gertler 2003 p. 1078). These agglomerations of producer services and their localized relations have elements of the “learning region” notion in economic geography literature (Section 2.2.3). The vertical dimension of learning is securely in place and as explained in detail in this study, is the primary stimulator and contributor to the innovativeness of KIPS firms. On the horizontal dimension, learning by observing, which is motivated by competition, provides impulses for functionalities and applications. The presence of the social dimension of localized learning, unintended encounters and knowledge spillovers can be observed at the conferences, symposia and networking events that take place in the region. As some of these occasions are heavily visited by actors from outside the region, these spillovers are not geographically bounded per se. These encounters are also not as unintended as they may appear at first sight, because participants state their desire to network with fellow specialists as the motivation behind participating in such events. As such, it can be suggested that software firms practice an active proximity management vis-à-vis their peers and customers (at least) at the regional level and co-create an environment of localized learning.

In this picture, there is a sizeable amount of path-dependency for automotive-oriented software services firms. This is hardly surprising, if one considers the fact that producer services are actually driven by demands from existing manufacturing industries. Therefore, for a given location, the pre-existing mix of activities in an automotive cluster largely confines the boundaries of development paths for software services activity. Especially for new and smaller firms, which have not yet built up working relations with other automotive locations, it is difficult to identify and absorb knowledge regarding alternative technologies and market trends. This situation poses potential risks for software firms on a location as they could fall into negative path dependencies associated with technological and organizational over-specialisation (Martin/Sunley 2006 p. 412). “Pipelines” with other locations are crucial for transplanting knowledge from elsewhere. This can be achieved through the software firms’ own supra-regional links. At the same time, larger enterprises in the automotive cluster, such as OEMs and Tier-Is, can potentially play more important roles in breaking such cases of lock-in by stimulating the up-grading of the cluster or by acting as pipelines themselves (Bathelt et al. 2004).

5. Summary of results and policy implications

5.1. Summary of results

In this section an evaluation of the hypotheses as well as individual answers to the research questions are presented. The background of the remarks and conclusions in the coming pages are to be found in the previously presented empirical results.

The hypotheses are presented below with the findings supporting or challenging their argumentations.

Hypothesis I: The presence of a geographical agglomeration of customers is a reason for specialized software firms to locate near existing industrial clusters.

Confirmed. The existence of a geographical agglomeration of customers influences software firms to locate nearby. This is true for the initial establishment of the enterprise as well as for during its organisational and geographical expansion. Software services firms establish their branch offices in and around agglomerations of customers.

Hypothesis II: Interaction with customers stimulates the innovativeness of software services firms.

Confirmed. Interaction with customers and addressing customers' existing or potential needs dominate the innovative behaviour of automotive-oriented software services firms.

Hypothesis III: The customers who are geographically proximate are stronger innovation stimulators for software services firms.

Confirmed. The relations with geographically proximate customers provide more frequent and detailed feedback and inputs for innovation.

Hypothesis IV: As a software services firm grows in size, the role of geographically proximate customers for innovation diminishes.

Partly confirmed. As the firm grows, it seeks to reduce its dependency on a limited number of customers or even sectors. This prompts the firms to create business relations with spatially-distanced customers. However, it is often the case that these firms also seek permanent spatial proximity to new customers by opening up branch offices in their vicinity.

Hypothesis V: For automotive firms, skills and service quality would be a more important criterion than geographical proximity for selecting software services suppliers.

Confirmed. Automotive firms tend not to invest in the basic training of their suppliers and expect these to pre-possess a certain level of competencies. For the customer, deficiencies in skills, quality and reliability create extra costs that cannot be made up with spatial proximity. Therefore ceteris paribus customers seek firms with the necessary skills at the first place.

Hypothesis VI: In order to prevent risks associated with new business partners, automotive firms would value trust-based long-term relations with software suppliers.

Confirmed. Positive shared experiences create trust in automotive firms, which motivates them to continue working with the same services suppliers. In addition, shared experiences increase the cognitive and organizational proximities between parties, which in turn improve the effectiveness of knowledge-production processes.

Hypothesis VII: With English as the established global working language and converging regulatory frameworks across trade-blocks such as the European Union, institutional proximity appears to be a negligible criterion.

Not confirmed. Although formal institutions are converging within the European Union, institutional mismatches (e.g. intellectual property laws) still exist, especially with non-EU countries. Besides, language is still a hindrance for tacit knowledge-intensive relations, as are the differences between national working habits and perceptions.

Research question I

What is the relation between the knowledge content of producer services and their spatial proximity requirements?

The development of industrial standards and process standardisation, which are strongly supported by globalized large enterprises, drive the ubiquification of layers of know-how across persons, enterprises and locations. The practical problems of communication between geographically distanced actors are consequently reduced, if not solved. Despite geographical and cultural spaces between them, actors can engage in knowledge-producing relations. As such, the ubiquification process turns geographical proximity between actors from a necessity into a preference. However, modern industries also depend on product and process innovations that are only realisable through the development and deployment of novel and untried knowledge, which is dependant on the sharing and reproduction of tacit knowledge of actors. For manufacturing sectors, the creation of such novelty is closely linked to KIPS and due to their customer orientation these services themselves depend heavily on dynamic tacit knowledge bases. As such, in order to be effective, KIPS firms do require F2F interaction with the users of their services.

What this study did not encounter, however, is a ubiquitous necessity to locate near customers permanently. KIPS firms operate in theme- or cross-specialized networks, which have characteristics of 'epistemic communities' or 'communities of practice' (Section 2.1.4). In these environments, the fundamental attachment of members is to specific types of knowledge, rather than geographical spaces. It has been found out that in such networks, together with the tacitness of knowledge content, coordination challenges influence the spatiality requirements of knowledge-production processes. These challenges primarily result from the time constraints and interfaces between knowledge-production processes.

Time pressure and economies of speed are two important factors in globalised markets. Under conditions where a highly tacit knowledge content has to be co-produced and shared in short time intervals across numerous processes run by different teams, actors and groups are compelled to engage in more frequent F2F interaction in order to avoid knowledge mismatches and misunderstandings. Therefore, despite the potency of ICT tools, economies of speed in knowledge-producing relations are still dependant on F2F interaction between persons. The serviceability of such processes that require frequent F2F interaction decreases with distance and increasing distance between partners escalates transaction costs, which in return compels parties to locate near one another (Sections 4.6.3 and 4.7).

Research question II

What is the relation between spatial and aspatial (social, organizational, institutional and cognitive) proximities for knowledge-intensive producer services?

Knowledge-intensive producer services are specialized affairs utilizing application- and customer-specific knowledge, which is at times very fluid, change-prone and not market-traded. Besides, the codes of communication and expressions of know-how are also sporadically standardized across application fields. Therefore, such environments display characteristics of communities of practice, where – without aspatial proximities – spatial proximity on its own cannot ensure communication across actors. On the other hand, aspatial proximities cannot be developed and sustained without spatial proximity between actors. For instance, social and cognitive proximities depend primarily on shared trust and specialized “languages” between actors (Section 4.6). Both of these factors grow through repeated F2F relations between persons and in areas where changes are frequent and the unplanned maintenance of aspatial proximities demands even more spatial proximity. ICT tools fail to stimulate aspatial proximities due to their impersonal nature.

However, once aspatial proximities are in place, they ease spatially distanced communication processes. The actors share knowledge openly and codified messages are understood more easily. For instance, strong organisational proximities within an enterprise enable a higher degree of openness and, supported by cognitive and social proximities, complex knowledge-producing relations can even be deployed across national borders. Nevertheless, temporary spatial proximity would still be necessary in order to refresh and strengthen aspatial proximities.

As Boschma states, it is easier for actors to manage aspatial proximities in horizontal and vertical dimensions in a cluster environment, where competition and cooperation processes are functioning (Boschma 2005 p. 72). By observation and interaction, they can gauge their cognitive, social and organisational distance to their customers and peers and react accordingly, practising what may be called “proximity-management”. Institutional proximity is also easier to establish when actors share a common geographical location. Indeed, excessive institutional gaps caused by spatial geographical distance, for instance divergent legal systems, can hinder interactive knowledge-production completely.

Research question III

What role is played by regional lead firms for knowledge-intensive producer services activity?

Provided that their local operations contain active technology-oriented knowledge-production functions, lead firms can act as the nodes of regional knowledge-production networks in the clusters in which they are located. The evidence collected for this study suggests that lead firms can create a sizeable demand for KIPS in monetary terms and thereby provide a critical basis to survive and grow. Additionally, lead firms can behave as demanding local customers à la Porter (Section 2.2.4) and stimulate KIPS firms with incentives and market-foretelling insights.

When a new technological application or service promises clear benefits, lead firms can even go beyond being consumers and actively co-produce novel knowledge together with their suppliers. Through these interactive processes, they share their tacit know-how with the KIPS firms; therefore, the service providers gain access to the knowledge capital of these lead firms, which would otherwise be inaccessible to outsiders. The know-how absorbed by KIPS enterprises is then directly or indirectly transferred to their other customers as they offer their services (Section 2.2.5). In this sense, lead customers support and co-develop the knowledge capital of their locations and in the case when they possess global operations, they have the potential to act as “global pipelines.”

At the firms level, however, the importance of lead firms does diminish for KIPS firms as the capacity and capabilities of these firms grow. In order to reduce their risks, KIPS firms seek to lessen their commercial dependency on and organisational proximity to lead customers. In niche markets such as software services for automotive industry, this often requires winning customers located elsewhere. As these supra-regional customer networks grow, the innovation stimulation effects are distributed across a larger customer portfolio and the role of demanding local customers recedes.

Research question IV

What can be inferred from the case of knowledge-intensive producer services for the discourse on regional structural change?

As a group of general purpose technologies, information and communication technologies (ICT) have contributed to the geographical transformation of the world economy. Especially for manufacturing activities, ICT provided the technological possibilities that enabled the coordination of spatially distributed networks. However, the analysis of software services for automotive industry underlined the resistance of knowledge-production to spatial dispersion. If we have a close look at the actor and firm level, knowledge production processes are closely related to the establishment and management of aspatial proximities that enable techno-social economic relations in networks. In theory, these networks can function independent of a fixed spatial node. Yet, especially for processes where cognitive dynamics and process complexity are high and the knowledge-content is highly tacit, the realm of relations between actors depends on the frequency of F2F interaction, which in turn warrants locating near business partners. For software services for automotive industry, the aggregated effect of aspatial proximity requirements has created concentrations of these producer-services firms around selected locations where knowledge-intensive activities of OEMs and Tier-I suppliers are present.

This picture suggests a degree of path dependency effects for knowledge-intensive producer services activity. For a given location, the pre-existing mix of activities in the local automotive sector largely confines the boundaries of development paths for software services activity. Especially for new and smaller firms, which have not yet built up working relations with other automotive locations, it is difficult to identify and absorb ways of thinking and alternative knowledge bases. This situation poses potential risks for the region as local actors can fall into negative path dependencies associated with technological and organizational over-specialisation (Section 2.3.2). However, the micro-level tendencies bounded with life-cycles of enterprises create a tendency for firms to branch out into other central locations. This kind of geographical extension tends to take place first within national borders and extends into other global automotive locations, thus creating “pipelines” to other know-how pools around the world. This phenomenon again is a product of the possibilities co-created by ICT tools. Therefore, geographical structural change in knowledge-intensive services does take place but with different dynamics than that of physical goods. For services, such spatially distanced knowledge-production services have a higher tendency to be bounded by the boundaries of enterprises. Meaning, the services are more often internally produced and consumed. The stronger aspatial proximities, especially along cognitive and organisational dimensions, ease the establishment and management of such services over political borders.

In this sense it can be argued that aspatial proximities decide the degree of absorption and utilisation of the structural change inducing technological revolutions.

5.2. Policy implications of the findings

Porter's cluster concept has been largely adapted in Europe as a template for sectoral support at the regional level (Section 2.2.2). The intension in this section is not to add to the criticism cluster-based support practices attract, but to provide feedback on the implementation of these activities. Such cluster support initiatives are very often supported or financed by public actors, who seem to focus their attention on the so-called new technologies and sectors such as bio-tech, ICT or media sectors. The rationale behind this action seems to be the idea "we will lose the manufacturing activities anyhow, let's do something future-oriented." This approach largely disregards the importance of local demand in Porter's model and how important spatially-proximate customers are for knowledge-intensive activity.

The innovativeness (hence the chances of success) of knowledge-intensive activities is closely linked to aspatial proximities to customers and customer groups. Especially for markets that are dominated by larger enterprises, it is ultimately important for smaller firms to maintain close links with the right persons in customer organizations. As this study has argued, the more sophisticated and knowledge-intensive business relations do benefit from co-locatedness, where actors can more easily develop and maintain aspatial proximities with their customers. Therefore, it would increase the success rate and sustainability of support initiatives, if they consider the links to the existing industries in their area, before they venture in to green-field cluster building actions.

On the other hand, the localisation effect of knowledge tacitness and the spatially centrifugal force of codification deserve more heed than they are getting at the moment. For instance, the AUTOSAR architectures, which are currently developed by an industry-wide cooperation platform, are bound to transform the spatiality of in-product software development by imposing general standards (Section 4.5). If AUTOSAR succeeds, availability of standards can potentially reduce the necessity of spatial and organisational proximity for development processes from today's levels. Consequently, it can be expected that the competition would increase to unseen levels. In such an environment of competition dominated by standards, the cost and the process quality would decide between winners from losers. For services sector, the most important cost variable is labour and regional policy makers could achieve little success in shaping labour costs. Seeking competitiveness on lower labour prices is not necessarily a sustainable winning-formula in itself. However, engagement of public actors can accelerate the diffusion of process and quality assurance standards across services enterprises, which would in return increase the competitiveness software enterprises. Especially smaller firms could benefit from initiatives to this end.

5.3. Open questions for future research

Boschma's model is an interesting starting point for the operationalisation of research questions regarding aspatial proximities and for this study, it proved to be a befitting tool to analyze the spatiality of automotive-intensive software services, from both the supply and demand sides. The layered model helped to untangle these relations from the influence of geography and also provided hints as to under which conditions spatially-distanced relations can function. On the background of this study, several areas of future research can be suggested. The relation between social and cognitive proximities deserves further interest as the two appear to be closely related at the actor level. These seem to bolster each other as knowledge of the transaction partner opens up possibilities for trust-based social interactions, which in return bolster cognitive proximity through these knowledge-intensive exchanges.

Secondly, institutional proximity and the evolution of its effect are an intriguing area as well. Institutional proximity is, as it were, the ground beneath other aspatial proximities and as such it co-defines the mechanisms of knowledge sharing and interactive learning (Boschma 2005 p. 68). Despite the convergence of formal institutions and the pervasive character of English as a business language, formal and informal institutions still have a strong effect on the decision behaviour of individual actors and firms.

Thirdly, the notion of organizational proximity is interesting in two separate ways. First, the effectiveness of high organizational proximity within enterprises as compared to traded relations in the context of spatially distanced knowledge-production needs to be studied. It appears that the boundaries of the firm are able to solve trust and knowledge related friction over distance. Similarly, the effect of imbalanced power structures across networks on proximity management and the consequences of customers' disproportional leverage on the geographical distribution of economic activity can provide new insights into spatial agglomeration and change.

On a different note, the data utilized for this study was collected from a sample of firms, which is largely indigenous in character. Therefore, it was not possible to gauge how branch offices and subsidiaries of German firms from other regions or of foreign enterprises have experienced establishing aspatial proximity relations with firms in the Stuttgart automotive cluster. Similarly, it would prove valuable to compare these arguments with respect to different locations with different institutional backgrounds and other sectors where business dynamics differ from automotive and software areas. The context for this question is that the institutional background has an influence on how social, cognitive and organizational proximities are shaped and it can be assumed that divergent sectoral characteristics are responsible for different decisions taken by actors’ with regard to aspatial and spatial proximities.

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