6. Summary, Conclusions and Future Research

This chapter summarizes the main findings and empirical results of this study. Concluding remarks, shortcomings and limitations of the conducted empirical analyses as well as suggestions for future research will be given.

The main objective of this study was to offer insights into the spatial distribution of research and inventorship activity (i.e., EPO patenting activity), core-periphery structures and co-patenting networks across European TL3 regions in the 1980s, 1990s and 2000s. In chapter 3, a special emphasis was placed on the spatial distribution and structural development of research clustering in different technology fields at the level of European TL3 regions. Furthermore, this study introduced a quantitative multidimensional measure of research clustering in a pan-European context. In addition to global clustering statistics, the quantitative cluster analysis identified leading European regions for a comprehensive number of technology fields. Furthermore, the strength of the identified research clusters was analyzed relating to the regional typology. Another major objective of this study was to identify and analyze the structure and development of technology field-specific inter-regional co-patenting (co-inventor) networks in Europe. For this reason, chapter 4 emphasized inter-regional co-patenting network linkages between European TL3 regions and countries for the periods 1990-1994 and 2000-2004. The analysis of inter-regional co-patenting linkages at the European TL3 level enabled global and local technology field-specific comparisons and conclusions. Finally, chapter 5 placed emphasis on the development of European regional income disparities and the determinants of regional growth between the 1990s and 2000s, with a special focus on regional patenting activity and the regional typology.

6.1. The Literature Review

Chapter 2 offered a theoretical and empirical literature review regarding core-periphery structures, agglomeration economies and research clustering.

The theoretical literature review (section 2.1) offered a review and discussion of a remarkable number of causes, working channels and stylized facts relating to location, co-location, agglomeration and co-agglomeration of industries, whereas special emphasis was placed on R&D clustering, research networks and the distribution of knowledge-intensive tasks. Research clustering, a.k.a. the geography of innovation, is challenged by several epistemic communities and approached in different strands of empirical research. Some researchers have particularly emphasized pecuniary externalities, linkages and formal networks at the firm-level in dense markets and industry agglomerations, whereas others have primarily devoted their attention to technological externalities, social networks, the nature of knowledge and the process of knowledge transmission. Nevertheless, both lines of research offered pivotal explanations for the observed skewed distribution of R&D activity, the emergence and disappearance of industry agglomerations and research clusters.

The theoretical approaches and concepts presented in the review differ with regard to the weight given to the different dimensions of agglomeration economies, the micro-foundations of knowledge transmission and the attention devoted to the spatial distribution of innovative activity in general (i.e., the “industrial” dimension, the “technological” dimension, the “geographic” dimension, the “socio-cultural” dimension, the “cognitive” dimension of clustering). The theoretical review demonstrated that the literature on clusters and agglomerations is manifold and that the different streams of research have co-evolved for decades with and without moments of cross-fertilization. In summary, almost all lines of research give support to the existence of pecuniary externalities, localized and inter-regional knowledge spillovers and flows. The theoretical review was elementary to identify pivotal indicators regarding knowledge-intensive industries and core-periphery structures. It was demonstrated that the spatial distribution of researchers, high-skilled workers, blueprints (i.e., patents) and GVA in knowledge-intensive industries is considered to be an essential indicator for innovative capacity and research clustering. Besides physical geography (i.e., first-nature), second-nature agglomeration economies generally emerge from sharing, matching, and learning mechanisms in industry agglomerations, metropolises and research clusters.

Accordingly, the theoretical review demonstrated that the origins of core-periphery structures are indeed multifaceted: (i) intra-market externalities (pecuniary externalities) that work via prices, (ii) quasi-market externalities (externalities from network transactions) and (iii) extra-market externalities (technological externalities) that occur without (complete) monetary compensation. Moreover, a general taxonomy was introduced, which was built upon the following pillars: (i) the spatial dimension of externalities (proximity/agglomeration vs. network link externalities); (ii) the effects of externalities (efficiency vs. innovation externalities); and (iii) the nature of externalities (pecuniary vs. non-pecuniary externalities). Regarding pecuniary externalities, the concepts of urbanization and localization economies were integrated (section 2.1.5). With regard to dynamic effects in agglomerations, the origins and effects of innovation (development) externalities (section 2.1.6) were addressed and special emphasis was placed on the concepts of Marshall-Arrow-Romer externalities (section 2.1.6.2), Jacobs externalities (section 2.1.6.3) and Porter externalities (section 2.1.6.4). Finally, special attention was given to knowledge generation and its transmission via anonymous market transactions, via (routine) network link transactions and via intentional and unintentional knowledge flows in networks at a proximate distance (section 2.1.7).

In conclusion, the intensity and overall effect of centripetal and centrifugal forces is largely dependent on economic integration, scale and scope economies, the spatial range of inter- and intra-industry knowledge spillovers, factor mobility and the presence of informal and formal networks. Although spatial proximity is generally beneficial for research activities and knowledge transmission, long-distance research networks and informal social networks also have the potential to overcome long distances and to enforce regional innovative capacities. Regarding these theoretical conclusions, the recent activities of the European institutions, the aim of which is to support and intensify inter-regional and cross-border research collaborations, can be considered to be a suitable step forward.

The empirical literature review in chapter 2 (section 2.2) has demonstrated that the research agendas of economists and geographers, regarding patenting activity, agglomeration economies and research clustering, mainly consist of the following lines of research: (i) the analysis of the spatial distribution of research activity and innovative capacities; (ii) the identification and in-depth analysis of clusters; (iii) the analysis of the different types of (R&D) knowledge spillovers and flows; (iv) the analysis of the spatial range of externalities and flows; (v) the identification and analysis of informal networks between firms and researchers; (vi) the analysis of researchers' mobility in a spatial context; and (vii) the identification and analysis of knowledge flows and externalities in formal R&D networks. Accordingly, the research lines can be divided into several dimensions: an "industrial" and "technological" dimension; a "geographic" dimension; a "socio-cultural" dimension and a "cognitive" dimension. The existing research lines represent combinations of these dimensions. Therefore, the empirical review summarized the main research results regarding these different approaches in the European context and discussed their advantages, disadvantages, major shortcomings and technical issues.

In reviewing studies relating to the distribution of research and patenting activity (section 2.2.2), the empirical review confirmed the lack of a pan-European empirical study on the spatial distribution of research and patenting activity. Empirical studies on the distribution and clustering of research and patenting activity have, unfortunately, occupied a rather minor position on research agendas. Most cross-country studies and national and regional studies focused on regional employment, GVA and production structures. Furthermore, most studies have directly challenged the effects and economic consequences of clustering and industry agglomeration with regard to employment, production and growth, but not the distribution itself. Accordingly, the trans-regional structures and dynamics of clustering remained unexplored in most studies, especially the global distribution and core-periphery structures of knowledge-intensive tasks, i.e. research and patenting activity. A comprehensive, harmonized and quantitative pan-European study, which analyzes the distribution of patenting activity over a large (nearly complete) number of technology field aggregates and all 819 European regions, and which covers the 1980s, 1990s and 2000s, did not previously exist to the author's knowledge. Moreover, the empirical literature was missing a harmonized, technology field-specific, quantitative research cluster study, which is built upon a balanced spatial classification system, and which identifies European research clusters in the entire population of 819 regions. Regarding the last three decades, it was rather unclear whether or not the whole population of the European regions in question was determined by a decrease, increase or a lack of change in the regional disparities in technology field-specific patenting activity and clustering. Therefore, chapter 3 in this study examined the distributional characteristics of patenting activity and identified European research clustering.

The empirical review also showed that the regional knowledge production function represents a pivotal empirical approach which combines the industrial, geographic and technological dimensions of agglomeration economies and knowledge production (section 2.2.3). Evidence regarding R&D spillovers and the relative ease of knowledge diffusion across agents' production functions and more aggregated spatial units is less ambiguous. The majority of European KPF studies affirms the presence of positive regional spillovers of R&D activity over up to 300-600 kilometers. The influence of neighboring regions' R&D

expenditures on other regions' patenting output is significant and positive in most European studies, but the working channels of spillovers remain a "black box" and are highly dependent on the implemented spatial classification system, i.e., the level of aggregation (MAUP), and the spatial weight matrix for constructing lagged covariates. Moreover, the empirical review also demonstrated that the differentiation between knowledge externalities and flows is extremely fuzzy in contemporary studies, as researchers use the terms "flows," "spillovers" and "externalities" interchangeably. Regarding this issue, the review also summarized the criticisms relating to the knowledge production function approach. The review essentially criticized the fatuous interpretation of significant spatial dependence (i.e., significant lagged covariates) in knowledge production function estimations as evidence for the presence of unintentional knowledge spillovers. From a methodological point of view, spatial dependence of regional patenting activity can be considered to originate from fractional counting of patent data at the regional level. Accordingly, spatial dependence could emerge as a by-product of meaningful co-patenting activities between neighboring regions. This idea has been challenged empirically in chapter 4.

Another debate which appeared in the literature on clusters is related to the relationship between local scale and industry specialization/diversity and its effects on regional productivity, innovative capacities and employment growth (section 2.2.4). Taking an "industrial" perspective, Marshall-Arrow-Romer externalities and Jacobs externalities (localization and urbanization economies respectively) are considered to affect intra-regional innovative capacities, employment growth and productivity gains. Regarding the innumerable quantity of studies, both types of agglomeration economies, localization and urbanization, showed positive coefficients as often as negative coefficients. Thus, it was argued that evidence on the dominance of one specific externality is not extensive enough to be compelling, and that studies have hit fairly rapidly decreasing returns. To conclude, regional studies on districts, milieus and clusters generally explain the incentives, causes and effects of agglomeration on the basis of the aforementioned different agglomeration economies, regardless of whether or not these effects are of an inter- or intra-industry type. Regarding this issue, regional specialization and diversity was challenged empirically in this study through an examination of technology field-specific research clusters across the 819 European regions with regard to their regional typology. Differences regarding research clustering between urban and rural regions were empirically challenged in chapter 3 (section 3.5).

With respect to the channels of knowledge transmission, it was demonstrated in the empirical review that the patent citation approach (section 2.2.5) can be regarded as the answer to elementary critiques regarding the existence and importance of knowledge spillovers. This approach combines an industrial, technological and geographic dimension of knowledge production and diffusion. Researchers have attempted to measure the existence and strength of knowledge flows directly by using patent citation data. The reviewed patent citation studies showed similar evidence, namely that knowledge, in terms of patents and their cited-citing ratio, is highly concentrated in space. Moreover, spatial distance exhibits negative effects on knowledge spillovers, although the negative effects of national borders seem to have vanished. However, the review also revealed problems and technical issues. It was demonstrated that inter-regional citation studies in most cases applied the standard NUTS classification, which generally leads to a severe bias in citation networks. This is a crucial concern, as the underlying spatial classification system is generally biased in terms of the absolute size of the regions. Furthermore, the citation approach ignores the major fraction of knowledge that is frequently transmitted via the market process and within intra- and inter-regional co-patenting networks. Moreover, the citation approach is problematic, because it is not clear whether or not knowledge spillovers, by means of documented patent citations, have really been realized. Almost 90% of all citations are traced by patent examiners, which raises severe doubts regarding the realized knowledge transmission between researchers. Due to the methodological disadvantages, drawbacks and technical issues discussed above, the patent citation approach was not applied in this study and a co-inventor network analysis was conducted instead (see chapter 4).

Regarding inter-regional linkages and networks, knowledge-intensive industries in clusters and regions are said to increasingly benefit from formal and informal network linkages between researchers. It was argued in section 2.2.6 that (informal) social network ties between researchers and their (former) colleagues are considered to be essential channels for tacit knowledge transmission. Spatial and social proximity both simplify the creation and extension of networks through which knowledge is transmitted. Therefore, empirical studies started to interpret and analyze cities and regions as interlinked places in a "space of flows." It is generally argued in the literature that tacit knowledge is mainly transmitted within networks, and that knowledge transmission at a proximate distance is highly dependent on the existence of localized networks between individuals. Accordingly, the review demonstrated that recent studies on social networks, inventor mobility, innovative milieus and epistemic communities place a special emphasis on the micro-foundations of knowledge transmission and the capacity of agents (and regions) to absorb appropriate tacit knowledge. Recent studies argued that regions are hosting technology-specific epistemic communities, which differ in terms of their group-specific technological specialization but also in their formal and informal institutions (e.g., skills, language, codifiability of knowledge, trust, norms) and diaspora. Accordingly, researchers have argued that the assumption that knowledge is a public good is a conscious exaggeration in growth models from the 1980s and 1990s, as knowledge is only partially non-rival and non-excludable (e.g., varying codifiability, property rights). Finally, the review summarized recent studies on social networks and researcher mobility, which confirmed the existence of highly localized researchers, and which indicated that (implicit) knowledge transmission is localized to the extent that networks are localized. A comprehensive analysis of social inventor networks in Europe is, however, limited due to severe data constraints regarding micro data on researchers' mobility.

In a final step, the analysis of inter-regional co-patenting networks was identified as the promising line of research in a pan-European context (section 2.2.7). In contrast to citation analysis, co-patenting studies make direct use of information on research collaborations between agents and regions. The linkages between regions can be directly interpreted as knowledge flows between agents (and regions). The empirical literature survey reviewed co-patenting and co-inventor studies, which are generally used in order to analyze the structures and dynamics of R&D collaboration activities in a regional and firm-level context. Firms, clusters and regions are considered to be increasingly benefiting from inflows of external forefront knowledge via network linkages to innovative neighborhoods, to global knowledge hot spots and centers of research excellence. The inflow of forefront knowledge is considered to depend increasingly upon long-distance research linkages between clusters and regions, but also on network transaction linkages at a proximate distance, i.e. within larger spatial aggregates (see chapter 2, sections 2.1.7.3 and 2.1.7.4). As inter-regional formal research collaboration networks are considered to enforce regional innovative capacities, knowledge transmission, cluster connectedness and regional interdependence, the analysis in chapter 4 placed special emphasis on co-patenting linkages. In conclusion, the review of co-patenting studies showed that there is still a relatively small body of studies on European inter-regional co-patenting activity. The review depicted the severe lack of a pan-European study on technology field-specific inter-regional co-patenting linkages.

To conclude, the review of the different strands of empirical studies on research clustering, research networks and regional disparities identified severe research gaps in a pan-European context. These gaps were challenged in chapters 3, 4 and 5.

6.2. Research Clustering in Europe

In chapter 3, the empirical analysis of the distribution of European regional research activity proceeded in two steps. In section 3.4, global distributional statistics on research activity across the entire population of the 819 regions in the ERA were presented. The study placed a special emphasis on the regional distribution of EPO patent application activity and EPO inventors since the 1980s in 51 technology field aggregates. Moreover, a harmonized, multidimensional research clustering index was introduced and the co-location of technology field-specific research clustering was explored in section 3.5. In addition to global statistics on research clustering, the section offered a comprehensive list of the leading European research cluster regions for 50 technology field aggregates. The empirical analysis of the distribution of patenting activity in Europe in chapter 3 was a first essential objective of this study and aimed to sharpen the cognition and to enrich the understanding of spatial structures, regional disparities and ongoing dynamics of research and patenting activities in Europe.

In a first step, the empirical analysis in section 3.4 contributed empirical findings on the structural dynamics of European inventorship activity in several ways. This analysis has to be recognized as exemplifying a purely quantitative "top-down" approach in the regional disparity and geographic concentration analysis tradition. The presented calculations are based on data extractions from the OECD RegPAT (January 2009) patent database and the OECD regional database. The implemented spatial classification covered 819 European regions, i.e., the TL3 regions of the EU-25, Switzerland and Norway. From a technology field point of view, the matching of IPC codes with 43 technology fields was accomplished through the application of the ISI-SPRU-OST-concordance (Schmoch *et al.*, 2003). In addition, the spatial characteristics of 6 high-technology fields (EUROSTAT, 2009) and 2 larger technology field aggregates were included in the analysis. The empirical analysis of regional disparity and the concentration of inventorship activity was enriched through the calculation of standard descriptives, e.g., patent densities (patents per million population, patents per square kilometer), kurtosis, skewness and percentiles of the distributions. The study demonstrated that the 819 European regions are increasingly filing patent applications at the EPO, which has led to an increasing number of less developed European regions with small numbers of EPO patent applications. Accordingly, the big picture is one of dispersion. In addition, revealed technological advantage (RTA) indices and Herfindahl-Hirschman indices (HHI) were computed, with the latter being an alternative measure of spatial concentration. Moreover, the analysis incorporated the computation of technology field-specific weighted Gini coefficients as population densities and areal surface characteristics differ tremendously across the 819 European TL3 regions. In this respect, the empirical analysis applied Gini computations at the regional level that explicitly accounted for spatial heterogeneity of observations in terms of regional population and area size. Furthermore, the analysis demonstrated that the distribution of EPO inventors (full counting) represents an acceptable proxy for EPO patent applications (fractional counting) across all technology fields. Several conclusions with regard to the technology fields which were analyzed and their spatial characteristics could be drawn from the quantitative analysis in section 3.4. First and foremost, the analysis identified highly skewed distributions of patenting activity across all technology fields, although the technology fields differ remarkably in terms of their development (dynamics) between the 1980s and 2000s. The analysis demonstrated that the 51 technology fields (including two larger aggregates) differed in terms of their geographic concentration across the 819 European TL3 regions. Technology-specific EPO patent applications and EPO inventors are, by and large, similarly concentrated across the 819 European regions. The average level of EPO patenting and research activity has increased since the 1980s in almost all technology fields. Accordingly, geographic dispersion has increased in the majority of technology fields since the 1980s. Nevertheless, even today, the majority of regions only account for small fractions of EPO patent applications and EPO inventors. The absolute number of specialized European regions ($RTA > 1$) has increased within the population of the 819 European TL3 regions. However, a larger share of European regions are involved in EPO patenting today compared to the 1980s and 1990s. Consequently, the share of specialized regions ($RTA > 1$), within the group of European regions that have at least a minimum level of patent application activity ($n > 0$) in a specific technology field, has decreased. Accordingly, Europe is determined by a process of ongoing dispersion, and decreasing relative concentration and specialization. High-technology fields show, on average, higher levels of regional disparity and thus geographic concentration compared to less R&D-intensive technology fields. Several high-technology fields are characterized by strong dispersion tendencies, e.g., *HT5 Communication technology, HT4 Semiconductors, HT2 Computer & office machines*, whereas patenting activity in *HT1 Aviation* and *HT3 Laser* remains relatively localized in a few European regions. Regarding weighted global disparity measures, and depending on the technology field under analysis, the computed locational Gini coefficients revealed more significant changes than their spatial alternatives. Regional disparity in terms of the spatial Gini was extraordinarily high in the 1980s. Both weighted Gini alternatives revealed a remarkable decline in spatial disparities in almost all technology fields. Nevertheless, it was demonstrated that the overall decline in regional disparities within the group of all 819 regions was accompanied by an increase in regional disparities within a small number of European member states. To conclude, the overall picture in a pan-European context is one of dispersion, which corresponds to the targets of the ERA.

In a second step, the cluster analysis in section 3.5 placed the emphasis on the identification and analysis of the spatial distribution of research clusters in the EU-25, Switzerland and Norway, i.e., the ERA. The empirical analysis of regional research clustering focused on 50 technology field aggregates, 819 TL3 regions and the periods 1990-1994 and 2000-2004.

A major contribution made by this analysis was the development of a multidimensional composite index at the regional level, the so-called "research cluster index" (RCI), which combined several coefficients relating to EPO patent applications, EPO inventors, regional population, areal size and research density. Based upon the computed RCI for each of the 819 European regions for all technology fields, the cluster analysis demonstrated that the majority of research clusters are located in leading European countries of the EU-15 and their core regions, predominantly in Germany, France, the Netherlands, Italy, the United Kingdom and Switzerland. The analysis also worked out that only a few EU-15 and Swiss regions exhibit high RCI values and that the 10 NMS still show weak research clustering. Furthermore, a list of the leading TOP20 European research cluster regions was reported, which gave support to the picture of skewed distributions relating to strong research clusters. Moreover, the RCI calculations demonstrated statistical evidence for co-agglomeration of patenting activity in a small number of leading locations.

Regarding regional specialization and diversity, the empirical analysis challenged the question of whether or not urban and metropolitan regions show, on average, more diversified research clustering structures compared to their rural counterparts. The cluster analysis unveiled that metropolitan areas and urban and capital regions exhibit a remarkably diversified research clustering structure compared to rural and intermediate regions. The analysis also identified persistent "north-south" and "east-west" gradients of strong research clustering, which is very similar to the results which were found with regard to regional growth and convergence (see chapter 5). It can be concluded from the cluster analysis that research clustering and diversified technology structures in the ERA are mainly restricted to capital regions and urban and metropolitan regions in the EU-15. Moreover, the analysis showed that rural regions are defined by a more specialized technology structure, as clustering (i.e., $RCI > 16$) can be only observed in a small number of technology fields (a few rural regions are exceptions). Thus, it is rather impossible to find technologically diversified research clusters in rural European regions, which represents a pivotal fact of the geography of innovation for policy programs. Furthermore, the analysis of research clustering at the regional level indicated that technological diversity in research activity can be found first and foremost in European capital regions, metro regions and their closest urban neighborhoods, e.g., Paris, London, Vienna, Berlin, Copenhagen, Stockholm, Nord-Holland, Bern, Oslo, Dublin, Budapest, Rome and Prague, which supports the theory of an urban hierarchy and distributional regularity of economic activity as has been proposed in urban economics (Duranton and Puga, 2001; Capello, 2007; Henderson, 2010). Regarding the former CEE-10 countries, several capital regions still showed only weak clustering in the 2000s, e.g., Budapest, Warsaw, Bratislava and Vilnius; moreover, a similar picture was presented for several EU-15 capital regions in Southern Europe, e.g., Athens, Cyprus (city), Malta (city). In southern European countries and the NMS, only Madrid, Rome, Lisbon and Riga show meaningful RCI values, but only in a small number of technology fields. Accordingly, the "east-west" and "north-south" gradients are still present in Europe, although meaningful dispersion across the hundreds of regions can be observed, especially since the 1990s. To conclude, the measure of research clustering for all 819 European TL3 regions across a comprehensive number of technology fields and its combination with the regional typology generated rich information on the "specialization-diversity" debate, although the analysis was restricted to a quantitative identification of co-agglomeration of clusters.

A clear shortcoming of the applied empirical approaches in sections 3.4 and 3.5 is their sole focus on quantitative measures and patent statistics. Unfortunately, all research activities which are not registered (and identified) via patent applications are completely ignored in the global disparity measures (section 3.4) and the research cluster analysis (section 3.5). Furthermore, the analysis completely ignored industry clustering (i.e., clustering of industry production, services and employment) due to its sole focus on the outcome of knowledge-intensive tasks. Moreover, pivotal aspects of clustering and the innovation process were completely excluded from the analyses, e.g., place-specific factors, history, regional institutions, regional policy. However, these shortcomings notwithstanding, the application of patent statistics represents the only possible way to construct a comprehensive quantitative pan-European measure with regard to hundreds of European regions. An alternative approach would have been to conduct more than 800 harmonized regional case studies, which was clearly beyond the scope of this study.

6.3. Inter-Regional Co-Patenting Linkages in Europe

Chapter 4 contributed to the research on relational patent statistics in several ways. In addition to spatial statistics on the geographical interdependence of research activity in Europe, the study provided specific empirical results relating to co-patenting activity in Europe. According to the empirical literature survey, and to the best of the author's knowledge, the empirical literature at the time of this study was missing a comprehensive study of the structures and dynamics of inter-regional co-patenting networks between the 819 European TL3 regions for a meaningful number of technology fields. Regarding this deficit in empirical studies, this study examined the structures and dynamics of inter-regional co-inventor networks and research collaborations between European regions (chapter 4). Special emphasis was placed on the structural development of inter-regional co-patenting linkages within larger TL2 regions, between larger TL2 regions but within national borders and inter-regional linkages between European countries. The results are the following:

In the first part of the chapter, section 4.2 offered statistical results regarding the existence and strength of spatial autocorrelation of patent densities by technology field at the regional level. It was demonstrated that the majority of technology fields are characterized by positive spatial autocorrelation for spatial distances up to 300-600 kilometers at the TL3 level, meaning that fractionally counted patent statistics exhibit spatial interdependence. The results confirmed the presence of strong spatial autocorrelation between neighboring regions, although the origin of spatial interdependence remained a "black box." Therefore, chapter 4 also introduced a complementary approach with which to address the issue of regional interdependence. The significance of spatial autocorrelation in patent statistics was challenged by explicitly taking into account the inter-regional "connectedness" of European regions and the presence of inter-regional research collaborations at a proximate distance between European regions, i.e., co-patenting activity. Accordingly, the empirical analyses in sections 4.3.4 and 4.3.5 aimed to directly address the existence of positive spatial autocorrelation in (fractionally counted) patent statistics at the regional level.

The second part of chapter 4 offered a descriptive analysis of European co-patenting activity with foreign co-inventors at the national level. Section 4.3.4 picked up recent debates on the internationalization of R&D, the emergence of international research collaborations and the integration of European countries into an expanding ERA. The empirical results of the cross-country co-patenting analysis pointed to meaningful tendencies towards an increase in international and European research collaborations (in terms of numbers and shares of co-patents with foreign co-inventors) since the 1990s, especially in the second half of the 1990s and the 2000s. That being the case, the average share of EPO patents with foreign co-inventors has increased considerably since the 1980s. It was demonstrated in the first part of the analysis that the group of co-patenting countries, in absolute (and relative) terms, is still predominantly dominated by a few countries, e.g., Germany, Switzerland, Belgium, the Netherlands, the United Kingdom, Sweden, Austria and Italy. The NMS are still determined by a very low level of co-patenting; however, co-patenting activity has increased in terms of absolute numbers and shares. Accordingly, the NMS have experienced a remarkable increase in EPO co-patenting activity with foreign European co-inventors, especially the Czech Republic, Hungary, Poland, Slovenia, the Slovak Republic and Latvia. Moreover, it was demonstrated that the European integration process, with regard to foreign co-patenting activity and R&D collaborations, gained momentum in the second half of the 1990s. Nevertheless, it has already been argued in the empirical review that national studies suffer from severe methodological drawbacks and that cross-country studies have also reached decreasing returns.

The third part, sections 4.3.5 and 4.3.6, offered a calculation of inter-regional linkages and global and local network statistics relating to inter-regional co-patenting activity. Empirical findings on European co-patenting network structures, geographical coincidence/co-location of networks and the centrality characteristics of technology-specific networks were presented in these sections. From a methodological perspective, it has been argued that research activity (i.e., EPO patent applications) generally leaves a paper trail in the form of patent documents, which can be examined when developing relational patent data.

Co-patenting linkages have been extracted for a comprehensive number of technology fields since 1980. In a following step, inter-regional networks were constructed from the extracted linkages, and global and local network statistics were computed which cover the entire population of the 819 European TL3 regions (EU-25, Switzerland and Norway). The reported global co-patenting statistics for each technology field cover: (i) the overall number and shares of interconnected regions; (ii) the number and shares of unique and overall inter-regional co-patenting linkages; (iii) the number and shares of inter- and intra-national linkages between regions. For the purpose of comparison, the study also incorporated additional calculations and analyses of the technology-specific inter-regional TL3 linkages that occur within and between larger European TL2 regions. The calculation and comparison of network linkages and nodes made it possible to depict potential distance decay effects and to combine the geographic and technological dimension of European inter-regional co-patenting activity. Furthermore, the analysis revealed structural changes in research co-operations and knowledge flows between the 1990s and 2000s.

The co-patenting study offered statistical evidence for the presence of highly localized European co-inventorship networks in almost all 43 technology fields. Although the networks are complex and heterogenous, a strong sense of localized connectedness between neighboring regions (TL3 and TL2 regions) in the form of inter-regional patenting activity could be identified. The majority of European co-patenting activity seems to happen at a proximate distance and has an intra-regional nature, meaning that a large fraction of research collaborations take place via inter-regional TL3 linkages within the administrative borders of larger TL2 regions. In addition, the results of this study confirm that approximately 90% of all European inter-regional co-patenting linkages occur between actors or organizations within the same country, which underlines the local nature of co-inventor activity. Even in the 2000s, a strong concentration of inter-regional research co-operations could be observed within the national borders of the respective European member states, although the overall share of these linkages has decreased in almost all technology fields. At the same time, international co-patenting linkages, i.e., inter-regional TL3 linkages between (TL1) countries, have increased in absolute numbers and shares. Moreover, the computations also covered the numbers and shares of unique inter-regional linkages. These unique linkages have expanded in absolute numbers in almost every technology field between the 1990s and 2000s. The analysis of the spatial range of inter-regional linkages within the two periods unveiled a significant structural change in European co-patenting activity. The calculations presented in this study provide some evidence that international linkages have increasingly replaced intra-national ones. The technology-specific shares of inter-regional-TL3 linkages between larger TL2 regions within the same country (inter-TL2 within country) have decreased, whereas the shares of inter-regional-TL3 linkages within larger TL2 regions (intra-TL2 within country) increased between the 1990s and 2000s. Furthermore, the shares of inter-regional linkages between countries have increased considerably between the 1990s and 2000s (inter-TL1/between country). Accordingly, the pan-European co-patenting analysis identified remarkable core-periphery structures but also meaningful structural changes with regard to long-distance research collaborations as reflected by co-patenting linkages. The presented results point to an ongoing dispersion of research collaborations and growth of the ERA.

Moreover, similar to the national co-patenting results (section 4.3.4), the performed regional analysis pointed to the presence of a European integration process of the NMS with regard to research collaboration activities at the level of the TL3 and TL2 regions. A deeper analysis of the extracted co-patenting linkages offered additional evidence regarding the presence of an ongoing integration of NMS regions into technology field-specific pan-European regional co-patenting networks. The numbers and shares of inter-regional linkages between the EU-15 group and the NMS group were calculated for the 1990s and 2000s. It is obvious from the presented tables and figures that the eastern part of Europe is being increasingly integrated into knowledge-intensive activities, as reflected by the numbers and shares of international co-patenting linkages between the EU-15 and NMS regions. Furthermore, the empirical analysis offered a comparison of the network structures of the 1990s and 2000s, using both global network statistics and network graphs for selected technology fields. The computed network graphs revealed considerable increases in the number of interconnected NMS regions, although the technology fields differed enormously in their spatial structure and overall dispersion. To sum up, the NMS regions, especially the urban, capital and metropolitan regions, have mostly been integrated into pan-European research networks, although these regions are only incorporated into a few technology fields. Regarding the aforementioned points, this study also provided local network statistics that are related to the individual position of regions in order to identify "hub-and-spoke network structures" and to explore the network centrality and connectedness of European regions by technology field. In this respect, some empirical evidence was reported which indicated that European regions differ in terms of their technology field-specific network centrality. The results confirmed that a few European regions dominate the European technology field-specific co-patenting networks due to their central position, which represents a crucial matter of fact for European regional policy and the European innovation system as a whole. Although co-patenting networks are generally increasing in the number of regions, the ERA is still dominated by a small group of leading research centers in the core regions of the EU-15. Nevertheless, the integration of NMS regions into inter-regional and international networks seems to have gained momentum since the 1990s, which has to be perceived by innovation policy at different spatial levels.

Finally, the analysis in chapter 4 provided preliminary results regarding the spatial coincidence/ co-location of co-patenting networks in regions (section 4.3.6). According to the presented results, technology-specific co-patenting networks seem to co-locate in a small number of European regions, which supports the hypothesis of technological diversification of co-inventorship activity in European regions (especially in capital regions and urban and metro regions). The TOP20 regions are in most cases the same TL3 regions across all analyzed technology fields, indicating that these regions are central nodes in different technology fields. The results obtained are complementary to the ones of the research clustering study (see chapter 3, section 3.5) and highlight a degree of regularity with regard to centrality. For a more detailed analysis of geographic coincidence and co-location, the computed network centrality indices were ranked at the TL2 level and Spearman rank correlation coefficients were calculated for all 43 technology fields. Regarding the obtained coefficients, it has been argued that the rankings of network centrality are similar across the technology fields, meaning that several European technology-specific co-patenting networks co-locate predominantly in the same European regions (i.e., urban areas, metropolises and capital regions), which confirms the hypotheses that (i) European regions are indeed "multi-field" research network nodes and (ii) that co-patenting activities are subject to certain spatial (urban) hierarchies and regularities.

To conclude, co-inventorship activity is increasingly inter-regional and border-crossing, meaning that policy makers have to realize the increasing connectedness and embeddedness of regions. It can be argued that the official statistics should pay much more attention to the relational aspect of patenting activity. Fractional counting of patent data represents an established method of analysis, but it is still possible for meaningful information to be lost. The results highlighted that patterns of inter-regional knowledge exchange and embeddedness differ tremendously across European regions. Regarding supra-national, national and regional innovation policy, policymakers have to take into account both the increasing inter-regional embeddedness of regions into networks and local innovation activities before starting any relevant policy action. Existing regional disparities and the increasing integration of regions into networks also demonstrate that best-practice innovation policies are hard to observe and cannot be implemented in different places without significant modifications. Policy programs and institutional changes could be regarded as a useful instrument when they increase the freedom of inter-regional research co-operation between different research locations. Nevertheless, the inter-regional European networks need additional research and the presented results have to be challenged by alternative methodologies (e.g., estimation of gravity models).

6.4. Regional Growth and Income Disparities in Europe

Finally, the study placed emphasis on regional growth, regional income disparities and core-periphery structures across European regions in chapter 5. Regarding regional growth, convergence and divergence in the European context, it remained an open question as to whether or not research activity (i.e., high-technology and non-high-technology research and patenting activity) and regional typologies (i.e., urban, rural, metro region) are positively related to regional GDP per capita growth at the TL3 level. Chapter 5 approached these deficits in two steps. Section 5.3 analyzed the development of regional income disparities and section 5.4 provided regional growth regressions at the TL3 level.

In the first part of the chapter (section 5.3), the study applied a measure of global income inequality, which clearly demonstrated that European countries exhibit different dynamics with regard to their within-country income disparities at the TL3 level. The analysis depicted different distributional patterns and revealed that not all countries are following the classical inverted U-shaped relationship proposed by Kuznets (1955) and Williamson (1965). The Kuznets curve is based upon the hypothesis that economic inequality increases while a country is developing, and then, after a certain average income is attained, inequality is said to decrease (Capello, 2007; Szörfi, 2007). The results do not support the presence of such an inverted U-shaped relationship for all European countries, but it is possible that the period of analysis was not long enough, as the inequality decomposition analysis only covered 12 years. This is a clear shortcoming of this study, which is, however, based on severe data constraints at the TL3 level stemming from EUROSTAT and the OECD (Combes and Overman, 2004). Nevertheless, the regional income inequality analysis revealed the following developments: (i) a decrease in inequality in Austria and Italy; (ii) a general increase in income inequality in Switzerland, the Czech Republic, Denmark, Estonia, Greece, Hungary, Ireland, Lithuania, the Netherlands, Portugal, Slovenia, Slovakia and the United Kingdom; and (iii) an inverted U-shaped trend in income inequality in Belgium, Germany, Spain, Finland, France and Sweden. That being the case, and based upon the global inequality analysis, it was argued that there is a general decreasing trend in regional disparities across the 819 European regions, whereas European countries revealed differing within-country disparities. However, it was also demonstrated that the decrease in global income disparities is mainly based upon decreasing between-country income disparities. A salient feature of the European regional growth process was elaborated on from the statistical decomposition of overall regional income disparities. Regarding the origins of inequality, it was useful to deconstruct global income disparities into between- and within-subgroup income disparities. In addition to the fact that overall income disparities have decreased across the entire population of the 819 European regions, the empirical analysis illustrated that the share of between-subgroup income disparities has decreased by approximately 15% since the year 1995. At the same time, within-subgroup income disparities have (relatively speaking) increased, meaning that several European countries experienced significant increases in their intra-national regional income disparities. It has been demonstrated that the EU-15 group is determined by a very similar overall trend of decreasing disparities compared to the entire population of the 819 regions, i.e., a meaningful decrease in overall inequality since 1995. Between-subgroup income disparity has decreased in a similar way to within-subgroup inequality. Moreover, it has been shown that between-subgroup inequality in the EU-15 today is at a very low level compared to within-subgroup inequality. With regard to the NMS, the inequality analysis clearly showed that the decrease in between-subgroup income disparities could not compensate for the observed increase in within-subgroup income disparities, which led to an overall increase in income disparities in the NMS. Therefore, it can be concluded that the group of NMS regions is determined by a strong asymmetric growth process, characterized by emerging core-periphery structures, and by exorbitantly positive GDP per capita growth rates in the capital and metropolitan regions, which supports the “growth poles picture” which was expanded upon by Williamson (1965).

Nevertheless, a severe shortcoming of the European income disparity study is the unavailability of longer time series, i.e., for the 1960s, 1970s and 1980s at the TL3 level. Criticisms made by other researchers regarding this issue have already been presented within the empirical review. Future studies may have the advantage of identifying and de-constructing regional disparities relating to additional economic indicators, i.e., GVA by industry, employment data at the 2-3 digit level and productivity statistics by industry. Generally, the official statistics of the EU need a superior harmonization, an improved data coverage and a stable provision of longer time series. Regarding the latter aspect, frequent changes in the spatial classification system (NUTS) are cumbersome.

In the second part of chapter 5, the regional inequality analysis was complemented by regional growth regressions (section 5.4). For the purpose of contributing to the convergence/divergence debate, this study analyzed a broad range of factors rather than specific growth determinants. Nevertheless, the empirical findings can be considered to contribute to a more realistic assessment of the process of regional development and to contribute with results relating to regional settlement typologies and regional growth. The results of the very general regression models therefore seem to support but also to extend existing regional studies. Unfortunately, due to the restricted set of covariates at the TL3 level, it was impossible to determine whether and to what extent the significant decrease in income disparities and regional convergence in the EU-15 was the result of neoclassical convergence accompanied by capital deepening and factor mobility, or whether it was a result of decreasing transaction costs in a new economic geography tradition, or based upon technological convergence via knowledge diffusion, technology transfer, or the result of disparity-reducing and gap-closing European regional cohesion policy. This aspect represents a serious shortcoming of the analysis which was performed. However, the methodological design could not be extended because of severe constraints regarding regional European data.

In line with several existing studies that have been conducted at a higher spatial level, the reduction of income disparities since the 1990s is assumed to originate predominantly from income convergence between EU-15 countries at the national level, but not between regions within nation states. Within-subgroup disparities are either constant or increasing. Although there is significant variation at the regional level, national characteristics (e.g., institutions, national networks, infrastructures and nation-specific macro-economic conditions in general) seem to determine the growth path of nations and their regions, as spatial dependence was not an issue when country dummy variables and a regional typology were implemented.

With regard to the regional typology (i.e., the settlement structure), metropolitan regions, urban regions and capital regions generally showed higher GDP per capita growth rates compared to rural and intermediate regions. Regarding the growth process in the NMS, capital regions have improved their position in the upper end of the regional income distribution. Unfortunately, the reasons for higher growth rates in urban areas and metropolitan and capital regions could not be determined or explored, as potential transmission channels were not explicitly modeled due to constraints regarding the data. Nevertheless, the implemented regional typology introduced a control for differences in the regional characteristics into the regression setup, e.g., urbanization, population size, infrastructure. The typology is thus regarded as to control in some way for the level of urbanization and thus agglomeration. Accordingly, the dummy variables for the regional typology may reflect agglomeration economies of an unknown type. Although countries have been generally converging since the 1990s, several factors have affected the average GDP per capita growth rate. The regressions confirmed that both the settlement structure and the regional knowledge/technology base are significant and positive, meaning that urban areas exhibit higher growth rates and that research (patenting) activity is positively related to regional growth. However, the reasons for the significance of the regional typology, i.e., urban regions, metro regions, capital regions, remain unclear. The significance may originate from MAR externalities and/or Jacobs externalities, from intra-regional R&D externalities in knowledge-intensive industries, or from static localization and/or urbanization effects (labor pooling, division of labor). We simply do not know as the regressions did not control for these channels due to severe data constraints. Nevertheless, the study clearly demonstrated that the regional typology and data on regional patenting activity implement meaningful additional information into regional growth regressions.

The presented shortcomings can be regarded as a crucial starting point for future research. Data coverage and harmonization are major problems regarding European regional studies. It is desirable that the harmonization and expansion of European regional data will proceed.

Finally, this study comes to the conclusion that place still matters a lot in the 21st century.