1. Innovative Places in Europe

1.1. Introduction and Motivation

Regional disparities and the processes of regional divergence and spatial clustering are ubiquitous in today's world. Researchers frequently point to the emergence and existence of dense urban areas and systems of cities around the globe (Krugman, 2009; Desmet and Rossi-Hansberg, 2010; Henderson, 2010).[1] They discuss the nature of the emergence and growth of metropolises, megalopolises and large core cities along seaboards and rivers, which are connected to large industrial belts (Acs, 2002; Fujita and Krugman, 2003; Combes and Overman, 2004).[2] Accordingly, the spatial clustering of production and employment is ubiquitous in regions across the world and is considered to be only partially dependent on physical geography.

Hinloopen and van Marrewijk (2004) reported an uneven distribution, irrespective of the kind of activity or level of economic and regional aggregation.[3] In the same vein, Krugman (1992, 5) has argued:

> "Step back and ask, what is the most striking feature of the geography of economic activity? The short answer is surely concentration [...] production is remarkably concentrated in space."

Once a core of economic activity has been established, be it a large city or an agglomerated region, it increases in overall size and processes of self-reinforcement increase its importance due to centripetal (agglomerative) forces and cumulative circular causation (Duranton and Puga, 2004; Combes *et al.*, 2008). Accordingly, the propensity of economic clustering can be observed on many spatial levels: the spread of blocks and downtown areas of metropolises; the formation of megalopolises; core-periphery structures at the regional level; the emergence of industry agglomerations within countries; and the spatial concentration of economic activity in a few countries within federal unions, e.g., the European Union (EU) and the United States (Combes and Overman, 2004; Fujita and Mori, 2005). Today, clustering is a phenomenon that determines the structure of both wealthy, industrialized regions and countries and also regions and countries which are in a period of transition (Duranton and Puga, 2004; Desmet and Rossi-Hansberg, 2010; Henderson, 2010).

Furthermore, Hinloopen and van Marrewijk (2004) mentioned several stylized facts which are related to the geography of economic activity. They argued that there exists a series of possible combinations of types of economic activity, its distribution, its economic and geographic aggregation, and the interaction between locations. The authors condensed the

1 See also Duranton and Puga (2004).
2 Refer also to Fujita and Mori (2005) and Florida *et al.* (2008).
3 Similar results have been reported by Brakman *et al.* (2005). See Audretsch and Feldman (1999) and Audretsch and Thurik (2001) for similar arguments.

real-world complexity of the distribution of economic activity to a few stylized facts and argued that: (i) the distribution is generally uneven, regardless of the type of economic activity; (ii) the distribution is generally uneven, regardless of the geographic aggregation level; (iii) the distribution is generally uneven, regardless of the level of economic aggregation; (iv) there is a remarkable regularity in the spatial distribution of economic activity; and (v) there exists a remarkable regularity in the interaction between regions and centers of economic activity.[4] This study aims to approach some of these stylized facts with special focus on research activity, i.e., patenting activity, research clustering and inter-regional co-patenting networks at the level of European regions.[5]

According to recent findings which have been recorded in the economic geography literature (Krugman, 2009; Fujita and Thisse, 2009), in the urban economics literature (Duranton and Puga, 2001; Henderson, 2010) and in the economics and geography of innovation literature (Feldman, 2000; Feldman and Kogler, 2010; Malecki, 2010), spatial structure should nowadays be challenged as a central determinant of distributional dynamics and regional development, particularly in the context of knowledge-intensive industries (Tichy, 1998; Capello, 2009; Feldman and Kogler, 2010). Geographic proximity is considered to be a crucial factor with regard to innovative activity and research clustering (Camagni, 1991b; Capello, 2009; Malecki, 2010). This argument is based upon the observed "tacitness" of knowledge, which is considered to enforce the spatial concentration of research activity and thus to increase regional disparities (Lissoni, 2001; Breschi and Lissoni, 2001a; Gertler, 2003). Countries are believed to progressively shift towards knowledge-based economies and thus to generate an increasing demand for basic knowledge and highly-skilled people (Feldman, 1999; Florida, 2002b; Foray and Lissoni, 2010).

A key argument which is discussed in the literature on inventorship location and co-location is that it is not only pecuniary transactions and formal collaborations in dense, anonymous markets that matter. Research collaborations in persistent R&D networks and informal social networks between researchers are considered to be of pivotal importance for research clusters and regional development.

From a theoretical point of view, geographical economics, economic geography proper and innovation system adherents have developed an established tradition of studying spatial clustering and agglomeration phenomena in respect to the benefits of geographical proximity for innovative activity, which is often labeled as "Marshallian externalities of the third kind" (Breschi and Lissoni, 2001a; Lissoni, 2001; Henderson, 2003a).[6] In addition to knowledge transmission via formal linkages, such as research collaborations, there is a wide consensus that knowledge spillovers constitute an important working channel for knowledge transfer at the individual and regional levels, and that these externalities have a positive

[4] See also Duranton and Puga (2001), Combes and Overman (2004) and Hinloopen and van Marrewijk (2006).

[5] Co-patenting or co-authorship refers to a situation in which a patent document/application either lists more than one individual as a designated inventor (co-inventor or co-assignee) or a patent is applied for by more than one individual. Within this study, the terms co-inventorship, co-authorship, co-inventing and co-patenting are used interchangeably, although the inventor address is applied in all analyses. Furthermore, the terms "research activity," "patenting activity" and "inventorship activity" are used interchangeably, although they are indeed not perfectly overlapping (see chapter 3, section 3.2).

[6] See also Duranton and Puga (2004).

effect on regional innovative capacity, inventive activity, per capita income, productivity and employment growth (Bottazzi and Peri, 2003; Moreno *et al.*, 2005a; Usai, 2008).[7] The main argument is that agents (researchers, entrepreneurs), located close by and especially in cities (and clusters), should be able to innovate faster than agents located in the periphery, as spatial proximity induces spatially bounded externalities and eases the transmission of distance-sensitive tacit and codified knowledge (Florida, 1995; Fujita and Thisse, 1996; Audretsch and Feldman, 2004).[8] It is generally argued that research collaborations and knowledge spillovers predominantly take place between neighboring regions over a short distance (Feldman, 1999; Lissoni, 2001; de Groot *et al.*, 2009).[9] High-technology industries in particular are believed to exhibit strong tendencies to cluster in space and to co-agglomerate across a small number of regions because of their strong dependence on specific labor and capital inputs, on the transfer of tacit knowledge within formal and informal networks, and on distance-sensitive down- and upstream interactions with suppliers and customers (Feldman, 1994b; Audretsch and Feldman, 1996, 1999; Scherngell, 2007).

However, it has also been argued that essential factors for production, e.g., technology-specific R&D tasks, are increasingly external to the region (Bathelt *et al.*, 2004; Powell and Giannella, 2010; Hoekman *et al.*, 2010). According to this argument, regions are becoming increasingly dependent on the inter-regional transmission of pieces of valuable information and knowledge. In this respect, several studies have mentioned that research activities show ongoing dispersion tendencies and that research collaboration increasingly takes place via long-distance linkages within inter-regional co-inventor networks between centers of research excellence. In this regard, research collaborations that shape inter-regional networks are assumed to represent pivotal carriers of tacit and codified knowledge (Johansson, 2005; Ejermo and Karlsson, 2006; Maggioni and Uberti, 2009).[10] For this reason, regions (and clusters) are considered to be positively affected by knowledge inflows, by their position in inter-regional research networks and by their international connectedness to knowledge hot spots and centers of excellence (Bathelt *et al.*, 2004; Saxenian, 2006, 2007).

Social and private marginal returns do not generally coincide in agglomerations and clusters, which is said to justify policy intervention (Duranton, 2008a). Regarding this issue, policy programs at the regional level, with the explicit aim to strengthen local and regional innovation potentialities, have become very popular within the last decade, especially at the European level but also across the OECD member states (OECD, 1999, 2007c,a, 2009a). European policymakers have shown, and are still showing, an increasing interest in regional policy programs, especially with regard to cluster creation and cluster promotion (Werker, 2006; PRO INNO Europe, 2010; Europe INNOVA, 2011).[11] Regional, national and European authorities are increasingly applying Science-Technology-Innovation (STI) policy programs in order to have an impact on the intra- and inter-regional growth potentialities, regional knowledge bases and regional absorptive capacities with regard to new knowledge and new technologies (Rodríguez-Pose, 2001; Vieregge and Dammer, 2007). In

[7] See also Greunz (2003a), Greunz (2004), Greunz (2005) and Crescenzi *et al.* (2007b).

[8] For an overview refer to Feldman (2000).

[9] See also Camagni (1991b) and Capello and Faggian (2005).

[10] See also Johnson *et al.* (2006).

[11] See, e.g., PRO INNO Europe (2010); Cluster Excellence (2011); Europe INNOVA (2011). Nevertheless, quantitative studies on the distribution are still missing.

this respect, regional programs on spatial clustering and inter-regional research networks are considered to intensify inter-regional knowledge flows and knowledge externalities, and to improve the attractiveness of high-technology (knowledge-intensive) locations for firms (Rodríguez-Pose and Fratesi, 2007; Hoekman *et al.*, 2010).

With regard to the European research landscape and the European cohesion and technology policy (i.e., the Europe 2020 program), three priorities can be identified (European Commission, 2011a,j): (i) smart growth and the development of a knowledge- and innovation-based economy; (ii) sustainable growth and the promotion of resource-efficient competitive industries and economies; (iii) inclusive growth, which enforces a high-employment economy with social, economic and territorial cohesion. According to the green paper of the European Commission, the intended "European Research Area" (ERA), as presented in Box 1.1, which is a policy tool but also an explicit policy target, is considered to serve several aims: (i) a significant interdisciplinary flow and exchange of researchers with high levels of mobility between institutions, regions, sectors and member states; (ii) excellent, interdependent infrastructures for research, accessible to research teams across the European regions; (iii) research organizations, which are engaged in public-private partnerships and co-operations, that are forming the core of European research clusters; (iv) clusters specialized in interdisciplinary areas and technologies and a critical mass of resources (see also Cluster Excellence, 2011); (v) an effective diffusion of knowledge between public and private research; (vi) European research programs, public research investment with common priorities, coordinated implementation and joint evaluation; (vii) increased openness of the ERA with an emphasis on neighboring regions and countries; and (viii) a clear vision and strong commitment among Europe's partners to addressing European and global challenges (European Commission, 2011a,j). With regard to the aforementioned features, the analysis of regional disparities and the clustering of European research activities and the identification and analysis of inter-regional research collaborations is considered to be of vital importance for a detailed understanding, conclusions and normative reflections.[12]

However, research agendas have mainly emphasized the structures and dynamics of European income distribution, the development of blue- and white-collar work, the effects of trade specialization and diversification on national growth, the effects of economic integration via freeness of trade and labor mobility, and changing national growth performances from a convergence-divergence perspective (Combes and Overman, 2004; Abreu *et al.*, 2005). Spatial disaggregation and the need for an explicit recognition of geographic characteristics and regional interdependence did not become a central issue until the late 1990s. As a consequence, the analysis of the distributional dynamics of knowledge-intensive tasks and processes, i.e., regional research and patenting activity, has only ever occupied an inferior position on research agendas and in regional studies (Combes and Overman, 2004; Harris, 2008). In contrast to the well-developed theoretical and empirical literature on the structures and dynamics of production and employment at the national level, the literature on research clustering, i.e., regional patenting activity, still offers unexplored fields and unanswered research questions. In the European context, it is argued that empirical studies on the distribution and clustering of research and patenting activity have, unfortu-

[12] For a comprehensive overview refer to European Commission (2011a,j). See also Werker (2006) for an overview of the European regional policy and Hagemann and Geiger (2009) for productivity developments in Europe, the New Economy and the Lisbon agenda.

nately, occupied a rather minor position on research agendas. Furthermore, the majority of studies focused directly on spillovers, growth effects or the micro-foundations of knowledge transmission (de Groot *et al.*, 2009; Beaudry and Schiffauerova, 2009). Fortunately, the empirical literature has grown considerably, and today contains a large number and variety of seminal qualitative case studies (Saxenian, 1990; Kenney and von Burg, 1999; Glaeser, 2005b) and quantitative studies of selected countries and predefined groups of regions (Archibugi and Pianta, 1992; Amiti, 1999; Midelfart-Knarvik *et al.*, 2004). Nevertheless, a comprehensive, harmonized and quantitative pan-European study at the regional level, which challenges the aforementioned issues for a meaningful number of technology fields, and which covers the 1980s, 1990s and 2000s, is still missing. Moreover, the empirical literature is still lacking a harmonized, technology field-specific quantitative research cluster study, which applies a balanced regional classification, and which identifies research clustering through the application of a harmonized, multidimensional measure for the entire population of the 819 European TL3 regions (Martin and Sunley, 2003). Regarding the last three decades, it is still unclear whether the entire population of European regions is characterized by a decrease, increase or a lack of change in regional disparities in technology field-specific research and patenting activity.

A glance at European patent statistics demonstrates that patenting activity has increased since the 1980s (van Zeebroeck *et al.*, 2008, 2009).[13] Figure 1.1 illustrates that the number of patent applications at the European Patent Office (EPO) has increased since the 1980s.[14] The largest fraction of EPO patent applications within the EU-27 group originates from the EU-15 countries. The New Member States (NMS, also CEEC) account for a small but increasing share of EPO patent applications.[15]

From a national perspective, figure 1.2 highlights the number of EPO patent applications by country since 1977.[16] This more disaggregated view demonstrates that patenting activity in Europe is highly skewed. Leading positions in patenting activity are occupied by, among others, Germany, France, Denmark, Italy, the United Kingdom, the Netherlands, Belgium, Sweden and Switzerland, and are today recognized as a stylized fact.[17] In comparison, the less prolific countries with regard to patenting activity include Estonia, Latvia, Bulgaria, Cyprus and Malta. However, even within the EU-15 group, Greece, Portugal and large parts of Italy and Spain show rather modest levels of patenting activity and represent, together with the NMS, the lower end of the distribution. Furthermore, it is obvious from these statistics that the NMS mainly started to file patent applications at the EPO in the second half of the 1990s.

The skewness of the distribution of EPO patent applications at the national level provides unambiguous evidence that research activity is generally unevenly distributed across coun-

[13] A similar trend is visible for patent applications at the USPTO by American inventors since 1985 (Kortum and Lerner, 1997; Hall and Ziedonis, 2001; Hall, 2005). Similarly, EPO President Benoît Battistelli has argued in January 2011 that *"[t]hese figures clearly indicate that demand for patent protection is on the rise again, after the economic downturn of the previous two years."* (European Patent Office, 2011c).

[14] For an overview of the structure and mission of the EPO refer to European Patent Office (2011b).

[15] The CEE-10 are also labeled New Member States (NMS). In the following, the terms CEEC, CEE-10 and NMS are used interchangeably.

[16] A complete list of the EU-27 countries and abbreviations is presented in table B.3 in the appendix.

[17] For a comprehensive overview, refer to Combes and Overman (2004) and Frietsch and Schmoch (2006).

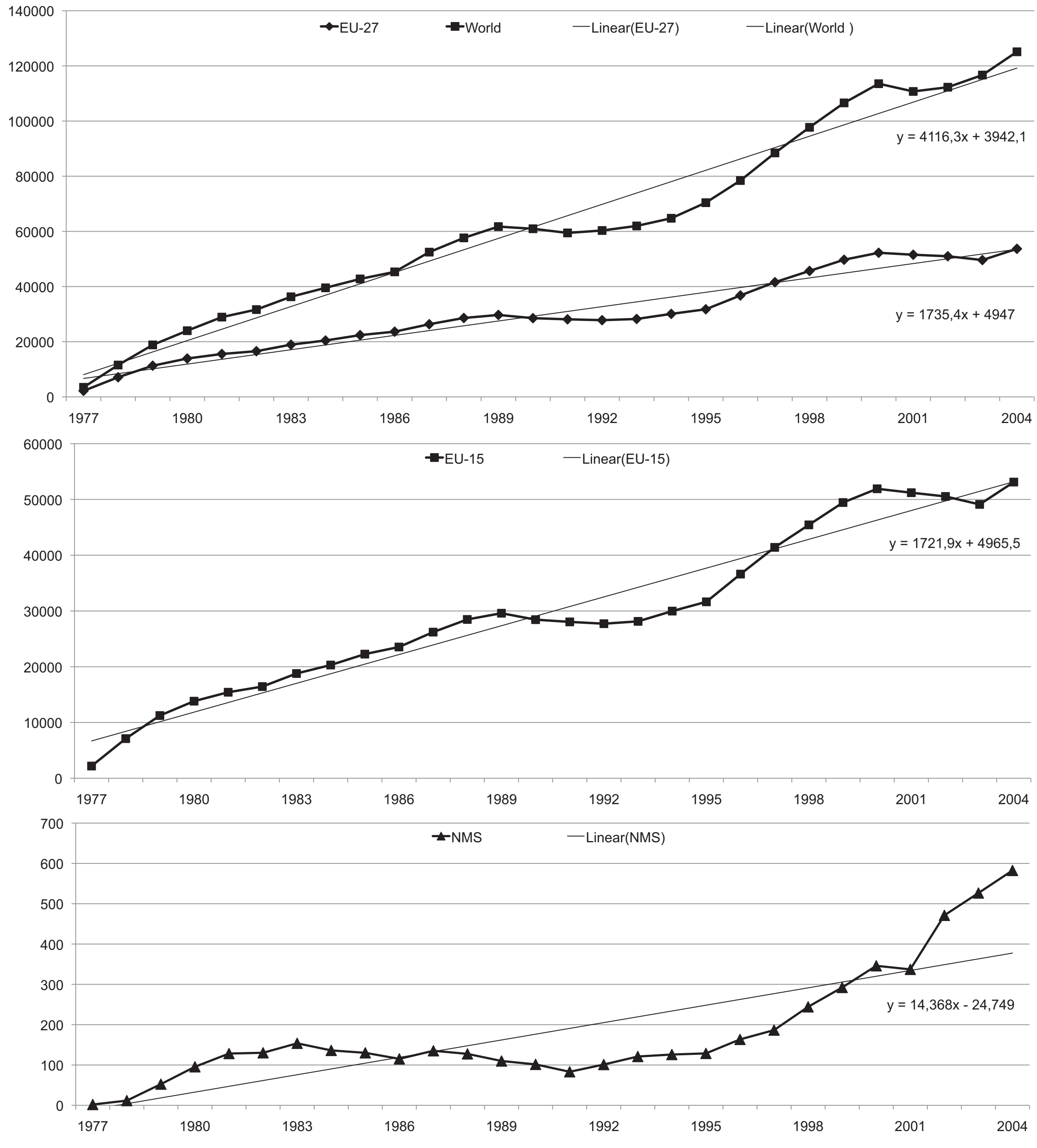

Fig. 1.1. Patent applications at the EPO 1977-2005
Source: own illustration. *Notes:* Number of EPO patent applications; data extracted from OECD RegPAT (January 2009) and OECD (2009d); fractional counts.

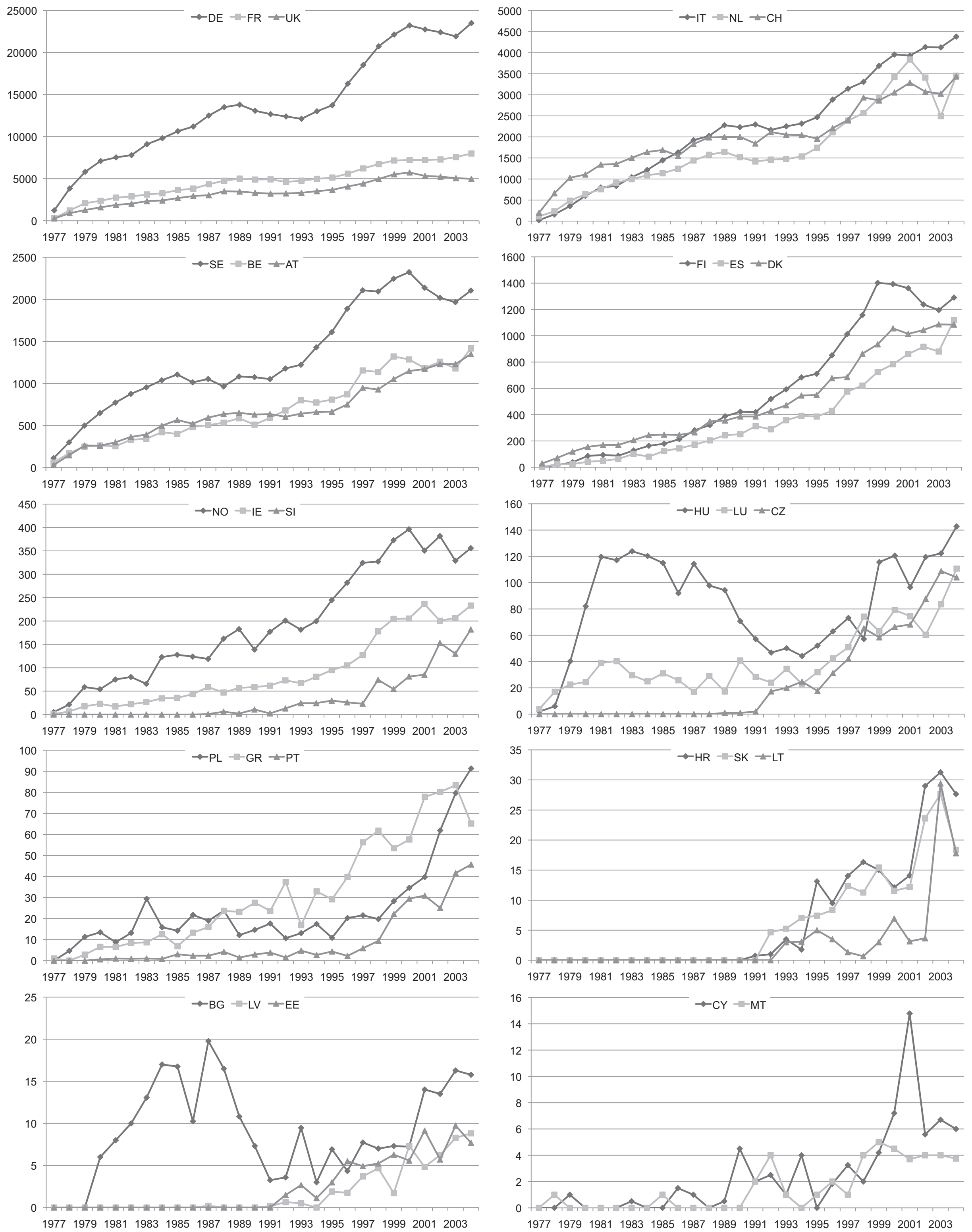

Fig. 1.2. Patent applications at the EPO 1977-2005 by country
Source: own illustration. *Notes:* Number of EPO patent applications; data extracted from OECD RegPAT (January 2009) and OECD (2009d); fractional counts.

tries. However, the observed national values and obvious national disparities are solely reflections of distributions at a more disaggregated level, i.e., at the regional level. According to Combes and Overman (2004), country-level studies and cross-country comparisons have hit fairly rapidly decreasing returns. In opposition, statements about economic activity at the regional level are much more difficult to make and, up to today, only a few trans-regional studies exist. There is a meaningful lack of comprehensive pan-European studies on inventorship distribution at the regional level. Unfortunately, regional R&D data for a comprehensive number of countries and regions at the TL3 level do not exist. In this respect, the analysis of patent statistics at the regional level is considered to be a key approach to unfolding and understanding the geographic nature and regional disparities in research (patenting) activity. Moreover, it is assumed that regional studies generally overcome the significant conceptual issues which are inherent in studies that are conducted at the national level, as meaningful processes and factors are only observable at lower levels of spatial aggregation, i.e., research clustering, the inter- and intra-regional migration of researchers and localized co-patenting networks within countries (Combes and Overman, 2004; Dewhurst and McCann, 2007). This is particularly a severe issue when normative conclusions and reflections have to be developed in a political economy context.

Taking into account the criticisms presented above, the following map (figure 1.3) highlights the regional densities of EPO patent applications (2003-2004) for the 819 European TL3 regions that represent the EU-25, Switzerland and Norway (OECD, 2003, 2006).[18] It is obvious that the distribution is highly skewed and that the European landscape of regions is determined by noticeable core-periphery structures.

It can be concluded that the aforementioned values of EPO patenting activity at the country level mainly result from a highly skewed distribution at the regional level. Accordingly, it seems that only a small fraction of European regions account for the majority of European research and patenting activities. Although the manifold economic factors and incentives that lead to agglomeration and clustering cannot be depicted in this study, it is nevertheless desirable for the empirical analyses to make an empirical contribution to the regional disparities illustrated above. This is one of the main objectives of this study. Hitherto, no pan-European studies exist that cover a comprehensive number of technology field aggregates and the entire population of European regions at the TL3 level. Therefore, this study presents and discusses methodologies and empirical results which are related to the structure and dynamics of research clustering and regional disparities in patenting activity in a comprehensive range of technology field aggregates in the 1980s, 1990s and 2000s, and covers the entire population of 819 European regions (EU-25, Switzerland and Norway). In addition, this study introduces a multidimensional research clustering index for harmonized global statistics and the identification of research/ innovation clusters in Europe.

Nevertheless, clustering of research and patenting activity represents only one structural aspect of the European research landscape. With regard to the previous waves of globalization, and in particular to the meaningful technological progress which has been made in the field of ICT, researchers frequently discuss the "death of distance" and "weightless

[18] Regarding data generation and methodological issues refer to chapter 3, section 3.3.

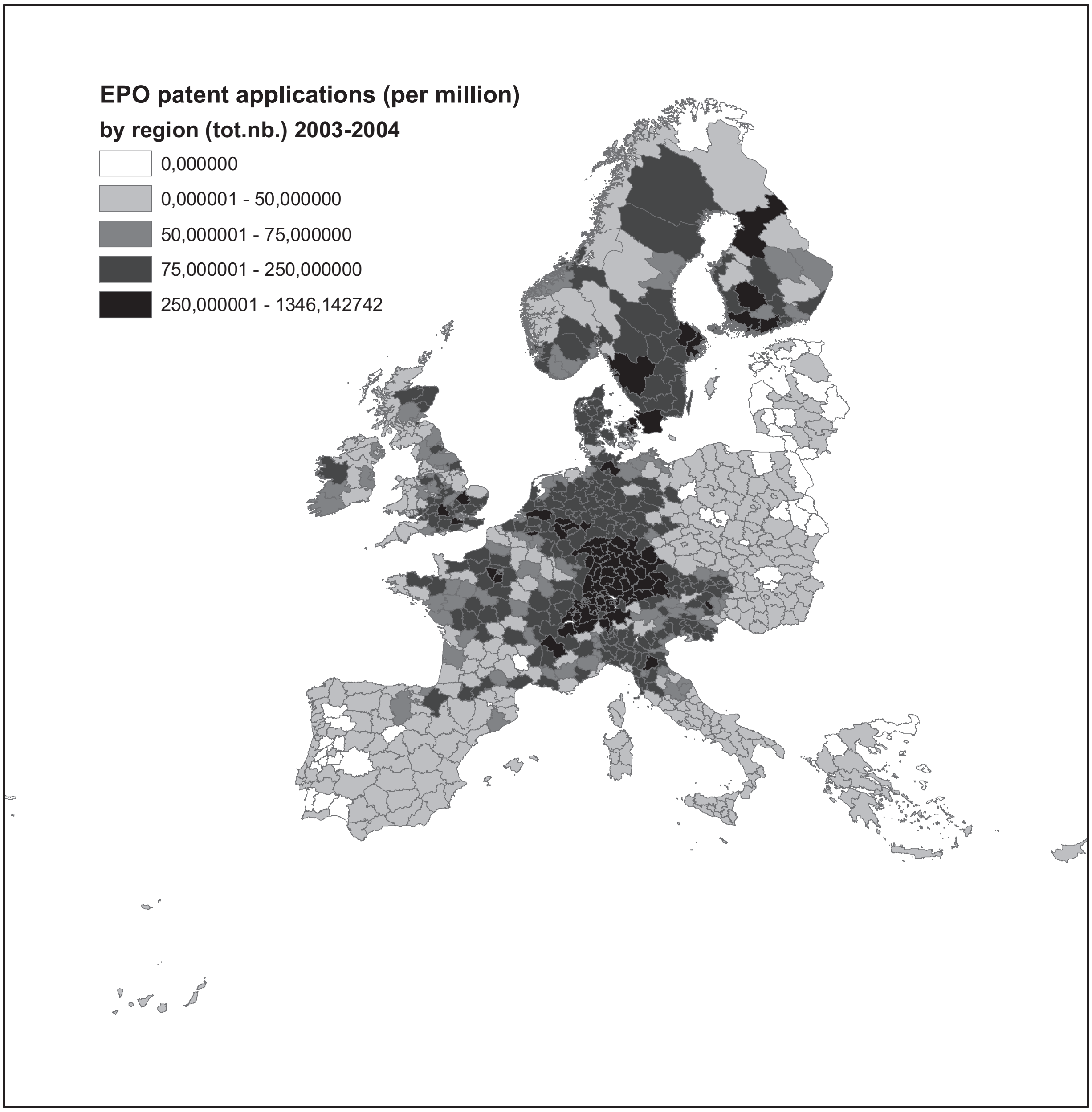

Fig. 1.3. EPO patent application density 2003-2004
Source: own calculations and illustration. *Notes:* EPO patent application density by region (per million population); data extracted from RegPAT (January 2009); fractional counts. Shapefile generation and polygon projection with ArcGIS 9.3.1. environment.

economy" (Audretsch, 1998; Giddens, 2000; Crafts and Venables, 2003).[19] Inter-regional research collaborations, such as border-crossing co-inventor activities in research networks, are considered to represent pivotal factors for regional development (Rodríguez-Pose and Crescenzi, 2008; Maggioni and Uberti, 2009; Capello, 2009). The internationalization of technology and R&D shows large cross-country differences (Guellec and van Pottelsberghe de la Potterie, 2001; Belitz *et al.*, 2006). However, the regional level has been the subject of only preliminary research. Furthermore, the analysis of patent data as relational data in this study is additionally motivated by the fact that European member states show an increasing number (and share) of EPO patent applications that originate from research activities and collaborations with foreign co-inventors and researchers located in other regions (Frietsch and Schmoch, 2006; Blind *et al.*, 2006).[20] Figure 1.4 illustrates this general trend at the country level for the European member states. However, it has to be argued that the observed co-patenting tendencies at the level of European member states are, once again, merely reflections of possible variations in developments at the regional level (Maggioni and Uberti, 2009; Hoekman *et al.*, 2010). Another crucial aspect is that different technology fields have different patenting propensities, which has to be taken into account in co-patenting studies (Frietsch and Schmoch, 2006). Therefore, co-inventorship activity and co-patenting networks have to be examined at both the regional and technological levels. In this respect, a pivotal part of the empirical analysis in this study is dedicated to inter-regional co-patenting network structures and their dynamics since the 1990s according to the different technology fields.

It has been argued in a few studies that European research networks are characterized by a significant dispersion and expansion (Hagedoorn, 2003; Paci and Usai, 2009; Hoekman *et al.*, 2010). Unfortunately, the empirical literature only shows a small amount of progress regarding the structure and dynamics of inter-regional co-patenting activity and technology field-specific co-inventor networks within and between European regions, as most studies have focused on single countries (Ejermo and Karlsson, 2004; Ponds *et al.*, 2010). A pan-European analysis of joint patenting for a comprehensive number of technology fields at the regional level does not exist. Hence, the structural characteristics and dynamics of inter-regional research networks at the level of smaller European regions, i.e., at the level of the 819 European TL3 regions of the enlarged EU, including Switzerland and Norway, are still unexplored. Regarding the geographic and technological dimension of European network structures, there is still a significant lack of knowledge and a continuing lack of research, which leads to a symptomatic deficit in positive results and normative reflections.[21] Accordingly, it is unclear whether the last two decades have brought about a stronger spatial dispersion or concentration of technology field-specific co-inventor networks. This research gap is best described by TerWal and Boschma (2009) and Malecki (2010), among others. TerWal and Boschma (2009, 742), albeit rather too pessimistically, argued that

[19] Refer also to Cairncross (2001).

[20] A co-inventor is an inventor whose name appears alongside the name of at least one other inventor in a patent application/patent document and who has contributed to the patented invention. Such a person is also called a "joint inventor" or "co-assignee." The terms "co-inventor," "co-patentee" and "co-assignee" will be used interchangeably in this study, as well as "co-inventor network," "co-patenting network" and "co-inventorship network."

[21] Malecki (2010, 505) has recently argued, *"[h]owever, we still know far too little about when - and whom and where - knowledge flows."*

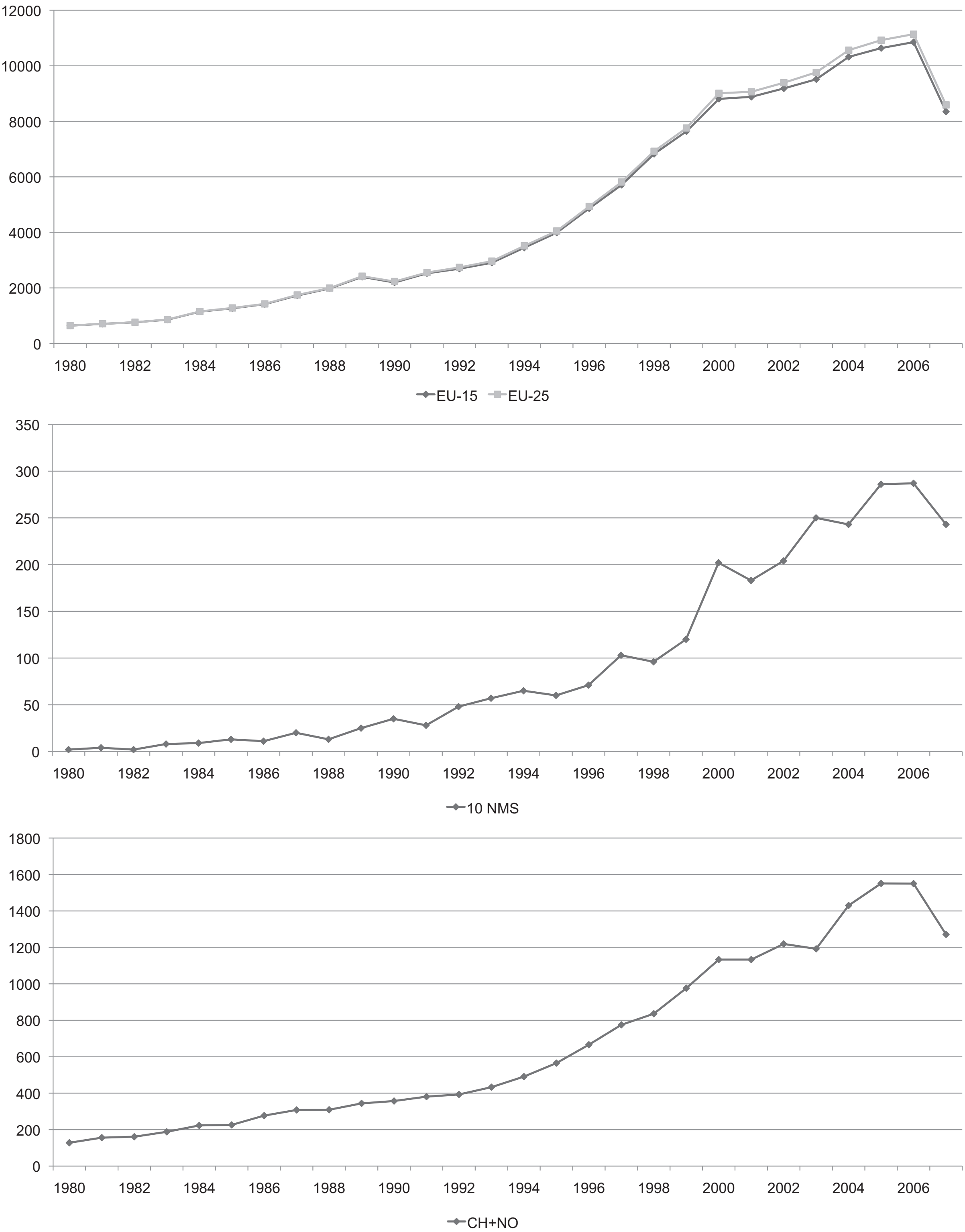

Fig. 1.4. Number of EPO patent applications with foreign co-inventors
Source: own calculations and illustration. *Notes:* Number of patents with foreign co-inventors since 1980 for selected country groups; total co-operations (EPO co-patents) with abroad; EU-15, EU-25, NMS and CH and NO; data extracted from RegPAT (January 2009) and OECD (2009d); fractional counts.

> "[v]irtually no studies on the dynamics of the structure of networks in space exist [...]. [F]urther research is needed on how the structure of networks evolves over time and space and, particularly, how the evolution of networks is related to the evolution of clusters. [...] treating patent data as relational data provides us with considerable opportunities to study the dynamics of regional innovation networks, which is, till today, a rather unexplored though promising field of study."

These impressions can be considered to be a starting point for the organization of a theoretical review and particularly for the development of the empirical research methodology applied in this study. A significant expansion of technology field-specific, inter-regional, border-crossing co-inventor networks, measured according to their inter-regional co-patenting linkages, can be interpreted as evidence for an increase in the number of inter-regional research collaborations and an ongoing integration of European regions into complex inter-regional European research networks. Such a development would correspond with the European Community's explicit target to create an integrated and dynamic research area (i.e., the ERA).[22]

To the best of the author's knowledge, this study is the first to analyze the structure and dynamics of inter-regional co-patenting networks between more than 800 European TL3 regions and a comprehensive number of technology fields. The main objective of this co-patenting analysis is to explore the development of inter-regional co-inventor networks since the 1990s and to identify key regions in these networks. Furthermore, the current position of the NMS regions in these networks is ambiguous. Similarly, evidence regarding the network position of the regions of the cohesion countries, i.e., Greece, Spain and Portugal, and the NMS is rather weak.[23]

Regarding income disparities and regional growth in Europe, the distribution of patenting activity may also be related to regional convergence of per capita income and the issues associated with technological congruence (Quah, 1996; Abreu *et al.*, 2005; Henderson, 2010). In a global context, income disparities are generally assumed to vanish as national per capita incomes show meaningful convergence in a cross-country perspective (Sala-i-Martin, 2006; Brakman and van Marrewijk, 2008). At the regional level, urbanization and development are considered to go hand-in-hand (Williamson, 1965; Henderson, 2010).[24] A natural starting point is the work of Kuznets (1955) and Williamson (1965) on income inequality and regional disparities. According to the Kuznets curve, developing countries suffer from a meaningful increase in income disparities in the earlier stages of development, followed by a decline in income disparities in later stages. The result is the popular inverted U-shaped relationship between per capita income and inequality. Williamson (1965) claimed that national development creates increasing regional disparities in the early stages of development, while later stages of regional development are characterized by regional convergence (Martin *et al.*, 2008; de Dominicis *et al.*, 2008; Henderson, 2010). Following Williamson (1965), regional disparities are said to increase at the beginning, because growth is mostly local and hence increases inequalities. It is argued that catching-up countries are mainly driven by a small number of regional "growth poles" in the early stages of development, in which physical capital, skilled workers and research activity are concentrated. Productivity,

[22] For further details on ERA, refer to European Commission (2011i).
[23] See also European Commission (2011g).
[24] For an overview refer to Capello (2007).

gross value added (GVA) and GDP per capita accelerate only in these core regions, which leads to significant increases in regional disparities and core-periphery structures (Szörfi, 2007). At later stages of economic development, these core regions exhibit higher factor costs (labor, capital, land) and meaningful diseconomies of agglomeration, i.e., centrifugal forces, which emerge in the growth pole regions and work against the centripetal forces. Then, capital accumulation and human capital are assumed to relocate to the periphery, where factor costs are lower, which finally leads to dispersion and some kind of convergence. Accordingly, it is argued that spatial concentration and inequality are part of the development process (World Bank, 2009; Henderson, 2010). Therefore, the study addresses whether or not capital regions and urban and metropolitan regions exhibit higher growth rates of GDP per capita between 1995 and 2006 and compares the NMS and the EU-15.

Regarding European enlargement, accession and cohesion countries generally undergo severe structural adjustments (Hagemann, 2004). With regard to regional development, economic and technological convergence represent essential targets of the European Community's policy (see Box 1.1).[25] It is therefore particularly important to analyze the development of regional disparities in per capita income in a pan-European context. Although European member states seem in general to converge at the national level with regard to economic activity, i.e., the legendary 2% rate of convergence (Sala-i-Martin, 1996; Hagemann, 2004; Abreu *et al.*, 2005), several studies point to persistent regional disparities or even divergence (Duro, 2004; Rodríguez-Pose and Fratesi, 2007).[26] Moreover, a few empirical studies reported preliminary evidence that regions within the 10 NMS are diverging, compared to the EU-15 group of regions (Rodríguez-Pose and Fratesi, 2007; Paas and Schlitte, 2008). At the same time, as a consequence of the European enlargement process, the core of European growth and the center of gravity for future regional European cohesion policy has expanded and shifted to the eastern and southern parts of Europe. Eastern European enlargement has induced an increase of more than 30% of the European areal surface and an increase in the European population of more than 25%, but neither a relevant increase in the average per capita GDP nor a meaningful increase in average research activity (Szörfi, 2007; Paas and Schlitte, 2008; European Commission, 2011b).[27]

However, one of the central European Community's objectives is to enhance economic and social cohesion within Europe. As a consequence, European enlargement activities and regional policy have to deal with the issue of considerable regional disparities within and between the European member states (Arbia *et al.*, 2005; European Commission, 2011h). The question arises of whether the initial income levels of poorer and technologically and economically backward regions (and countries) will converge to the level of the leading industrialized European core regions (and countries), which has essential implications for future regional growth paths, integration policy, structural funding and STI policy targeted at the regional level (Rodríguez-Pose and Fratesi, 2007). Regarding innovative capacities (i.e., research and patenting activities), it is still an open question as to whether or not patenting activity (i.e., high-technology and non high-technology patenting activity) is positively related to regional growth. Furthermore, to the author's knowledge, growth

[25] See also European Commission (2011i).

[26] For further details refer to Abreu *et al.* (2005), Brülhart and Traeger (2005), Szörfi (2007), Paas and Schlitte (2008) and Crespo Cuaresma *et al.* (2010).

[27] For more details refer to European Commission (2011e).

regressions at the TL3 level which control for regional typologies are still missing in a European context.

Box 1.1: The European Research Area

The creation of the so-called European Research Area (ERA) was suggested by the European Commission (EC) in its official communication "Towards a European Research Area" (European Commission, 2000, 2007b; European Council, 2010; European Commission, 2011b,j). The objective of creating the ERA was affirmed by the European Union at the Lisbon European Council (in March 2000). The construction of the ERA is considered to work against the past fragmentation of the European research landscape and knowledge economy. Accordingly, the ERA represents the general idea of implementing and supporting a coherent policy framework, which is considered to be conducive to European research activities. The ERA programs aim to mobilize a critical mass of research(ers), to reduce costly overlaps in knowledge-intensive tasks and to improve research efficiency. Another aspect of the ERA is the coordination and integration of mechanisms involving all levels of policy intervention in Europe (European Commission, 2011b). The ERA also aims to achieve an increase in coherence at the level of European regions. Convergence (i.e., dispersion of R&D, GDP, GVA) is one of the key policy foci (see also chapter 5, Box 5.1). Several programs and actions have been started in order to enforce the establishment of the ERA (e.g., a threshold target for the European R&D investment intensity at 3% of countries' GDP) (European Commission, 2011a). Research, education and innovation are particularly considered to represent the key drivers within the knowledge-based society and future industries. In order to establish the ERA, research is regarded as to develop strong(er) linkages to education and innovation (European Commission, 2007a, 2011b,j).

The ERA includes several key programs and general frameworks. These European initiatives are considered to represent valuable steps for further progress (European Commission, 2011b,j).

After a first stage of development (2000-2006), the ERA experienced a renewal and strategic advancement in 2007 with the publication of the green paper on its future development (European Commission, 2007a, 2011b). In 2008, the member states and the EC defined the so-called "2020 Vision" for the ERA, i.e., the "Ljubljana Process" (European Commission, 2011j). The member states launched several partnership initiatives to affect several areas: the co-operation and mobility of researchers; the personal careers and working conditions; joint research programs; the support and creation of modern research infrastructures; increasing knowledge transfer and co-operation between industry and public research organizations; international co-operation in science and technology (European Commission, 2011b,j).

To conclude, the thesis aims to contribute with global findings on the distribution of European inventorship/ research activity, with an alternative "top-down" cluster analysis and a very general identification and structural analysis of inter-regional co-patenting linkages (and networks) in a pan-European context. In addition, the study offers an analysis of European regional income disparities and regional growth. Special emphasis is placed on the significance of the regional settlement structure; it is tested whether or not capital regions and urban and metropolitan regions exhibit higher growth rates of GDP per capita. As the spatial distribution of knowledge stocks and researchers is considered a crucial factor for regional development, persistent core-periphery structures in patenting activities should then be reflected in significant differences regarding regional growth rates. This hypothesis is empirically addressed in chapter 5.

1.2. Outline of the Thesis and Research Questions

With regard to the aforementioned research gaps and issues, the main objective of this study is to elaborate on the development of the regional disparities and territorial dynamics of patenting activity in Europe and to analyze the development of European inter-regional co-patenting linkages and network structures. Moreover, pan-European growth regressions at the regional level complement this study. The study is organized in six chapters.

The literature survey in the second chapter offers the theoretical and empirical foundation for the subsequent empirical analyses. It reviews major mechanisms, causes and effects that determine the spatial distribution of knowledge-intensive activities and the emergence, stability and growth of clusters and core-periphery structures.

The first part of the literature survey offers a review of different schools of thought that challenge agglomeration economies, clustering, spatial concentration, co-agglomeration and networks, and outlines the relevant theoretical debates (section 2.1.1). The main objective is to elaborate on the different mechanisms which lead to a skewed geographic distribution and clustering of research and patenting activity, i.e. core-periphery structures.[28] The theoretical review addresses core-periphery structures relating to first- and second-nature causes and effects of co-location, agglomeration and co-agglomeration, paying special attention to the distribution of research and patenting activity. In opposition to first-nature causes of agglomeration and clustering, second-nature agglomerative forces are independent from physical geography. In this context, the concepts of the division of labor and indivisibilities (section 2.1.3) and the well-known concept of external economies (section 2.1.4) are presented, as they bring together the different epistemic communities. With regard to external economies, the theoretical review discusses the concept of pecuniary and non-pecuniary externalities and the concept of urbanization and localization economies and offers a detailed taxonomy (sections 2.1.4.3, 2.1.5 and 2.1.6). Regarding pecuniary externalities, section 2.1.5.5 briefly reviews the central conclusions of pivotal new economic geography models, which offer some theoretical working channels of clustering and the relocation of economic activity. In this respect, the crucial drawbacks of early new economic geography models will be discussed, especially those relating to the missing channels of knowledge diffusion and their inability to explain research clustering and the (re-)location of knowledge intensive tasks. Regarding technological externalities, an emphasis will be placed upon the missing circular causalities and cumulative causations in endogenous growth models in section 2.1.6.6. It is argued that, although these models address knowledge externalities as the pivotal reason for persistent regional disparities, they are generally unsuited to explaining the process of industry agglomeration via relocation and research clustering dynamics. The subsequent section 2.1.6.7 then briefly reviews new economic geography growth models (growth-cum-geography models) and offers conclusions with respect to research clustering and the development of regional disparities. Finally, the theoretical review in section 2.1.7 is extended to issues relating to knowledge spillovers, knowledge flows, linkages and the effects of knowledge attributes on research clustering, with a special focus on knowledge-intensive industries, research clustering and inter-regional co-patenting networks. Essential

28 Co-agglomeration is defined as agglomeration of two or more technology fields/industries in the same location; co-location, in comparison, is defined as the siting of two or more firms in the same location that form an agglomeration (Roos, 2002, 168; Gallagher, 2008).

elements in this context are distance decay effects and the possible spatial overlaps of agglomerations and networks. Knowledge transmission is considered to be dependent on the different attributes of knowledge, i.e., tacitness, codification, excludability and rivalry. Regarding the nature of inventive collaboration, the review differentiates between research collaborations and knowledge flows within long-distance networks on the one hand and spillovers at a proximate distance on the other. Section 2.1.7.5 discusses the tension between region-specific agglomeration economies at a proximate distance and the benefits of external knowledge that enters the region via inter-regional research linkages.

The second part of the chapter (section 2.2) represents the empirical literature survey. It offers a review of the current state of research and the different strands of empirical analysis (section 2.2.1), which are related to the distribution of research activities in Europe, the distribution of research networks and the analysis of knowledge flows and spillovers. In addition to discussing methodological issues and the empirical results of studies on the concentration and regional disparities of patenting activities in Europe (section 2.2.2), the review also addresses the regional knowledge production function approach (section 2.2.3), the localization-urbanization approach (section 2.2.4), the patent citation approach (section 2.2.5), the social network and inventor mobility approach (section 2.2.6), and the co-patenting/co-inventor network approach (section 2.2.7). The empirical review is essential to work out the advantages, drawbacks and shortcomings of central research approaches, to develop a comprehensive database and to define the research methodology for own empirical analyses. The review will demonstrate a meaningful need for additional empirical research on regional disparities in patenting activity and on the structures and development of European inter-regional co-patenting network linkages.

The third chapter represents the first empirical part of the study and offers a detailed descriptive analysis of the regional disparities of European research activities, i.e. EPO patenting activities. This analysis provides insights into the structure and distribution of patenting activity across European regions. Moreover, the analysis incorporates a multidimensional quantitative approach for the identification of research clusters at the regional level.

In the first part of the chapter, section 3.1 introduces the research topic. The subsequent section 3.2 presents the central issues relating to the application of patent data and section 3.3 introduces the regional database and applied spatial classification system. The analysis uses extractions of EPO patent applications (fractional counting) and EPO inventor IDs (full counting) based on OECD RegPAT data (January 2009) and links them to 819 European TL3 regions (EU-25, Switzerland and Norway). All EPO patent applications between 1977 and 2007 are regionalized and linked to 43 technology fields (ISI-SPRU-OST concordance) and 6 high-technology fields EUROSTAT (2009). In section 3.4, the analysis focuses on regional disparities and spatial concentration of research activities in Europe, i.e., patent applications at the EPO. The analysis contributes empirical findings on the distribution and geographic concentration of European patenting activity at the level of European TL3 regions according to technology field and country. Global descriptive distributional measures are applied in order to answer the question of whether or not overall EPO patenting activity according to technology field is highly concentrated and therefore unevenly distributed across European countries and regions. In addition, the empirical analysis answers the question of whether or not Europe is determined by an increasing share of specialized regions, and whether technology fields in general have shown tendencies of spatial dispersion within the last two decades. Besides reporting the standard descriptives, the empirical analysis also covers Herfindahl-Hirschman indices, location quotients, relative patent densities, revealed technological advantage indices and Gini coefficients. The Gini calculations explicitly take into account the heterogeneity of regions in terms of regional population and area size.

In the second part, section 3.5 offers a descriptive framework for identifying research clustering in the European research landscape, i.e., the ERA. A harmonized, multidimensional descriptive measure of research clustering at the regional level is introduced. The proposed research cluster index (RCI) uses information on regional EPO patenting activities and EPO inventors according to technology field and region, as well as information on regional population, the size of the area and relative regional specialization. Based upon the computed RCI, the empirical analysis emphasizes global statistics on European research clustering by technology field and country and the identification of leading research clusters according to technology field and country (number, share, strength of clusters). The computation of the RCI for two periods, 1990-1994 and 2000-2004, offers the opportunity for a dynamic analysis. The empirical analysis additionally links the computed technology-specific RCI to the regional settlement structure in order to examine whether or not urban and metropolitan European regions host a remarkably larger number of technology-specific research clusters compared to intermediate and rural regions. Moreover, the computed RCI is used to examine core-periphery structures in Europe, i.e., north-south and/or east-west gradients, with a particular focus on the emergence and development of research clusters in leading EU-15 countries and the NMS. This chapter also offers empirical results regarding the geographic coincidence/ co-agglomeration of research clusters at the regional level relating to the regional typology (i.e., capital regions, metro regions, urban and rural regions).

In the fourth chapter of this study, the empirical analysis places the emphasis on the identification and exploration of European inter-regional co-patenting networks and the analysis of spatial interdependence of EPO patenting activities at the regional level.

Section 4.1 represents the introductory part of the chapter. In the first empirical part of the chapter (section 4.2), issues of spatial interdependence and regional spillovers from patenting activity are discussed. Strong regional disparities in patenting activity may be accompanied by spatial autocorrelation of regional EPO patenting activity. An explanatory spatial data analysis (ESDA) is used to test for the presence of spatial dependence of EPO patenting activity in 51 technology field aggregates. The analysis of different spatial distance bands addresses distance decay effects and functional boundaries. In the second part, the chapter addresses innovative collaboration, i.e., co-patenting activity (section 4.3). The methodology and relational database are presented and discussed in sections 4.3.1, 4.3.2 and 4.3.3. In a first step (section 4.3.4), the empirical analysis emphasizes co-patenting activity at the national level. Therefore, the analysis explores foreign co-patenting activities of the European member states since the 1980s. Border-crossing collaborations between European researchers and fractional counting of patent applications may represent possible origins of significant and positive spatial dependence. The empirical analysis of international co-inventor activity focuses on the absolute numbers and shares of EPO patent applications with foreign co-inventors since the early 1980s. The study presents results for the EU-15 and NMS group and for selected extra-European countries (e.g., Switzerland and Norway) and examines whether or not co-patenting activity with foreign co-inventors from other countries has increased since the 1980s. The analysis of co-patenting activity at the country level represents a necessary pre-analysis for the subsequent co-patenting study at the regional level. In a second step, the study presents empirical results relating to co-patenting linkages (and networks) between European regions (section 4.3.5). Based on EPO co-patenting information for the reference periods 1990-1994 and 2000-2004, the empirical analysis places the emphasis on the spatial configuration of 43 technology field-specific co-patenting networks between European regions at different spatial levels (TL3 regions, TL2 regions and TL1 countries). The study analyzes whether or not these 43 technology field-specific co-patenting networks differ in terms of their overall size (nodes, linkages) and whether or not the networks are dominated by similar groupings of regions. The comparison of the networks at different spatial levels aims to distinguish between inter- and intra-regional co-patenting linkages, as spatial aggregation to larger regions transforms inter-regional linkages into intra-regional ones. The empirical analysis of the overall and unique network linkages contributes to a detailed picture and understanding of European research network structures. In addition to global network statistics (network size, nodes, unique and overall linkages), the empirical analysis also contributes local network statistics, i.e., the network centrality of regions (degree, betweenness). The analysis identifies the core-units of European technology field-specific co-patenting networks, but also the most peripheral regions. From a core-periphery perspective, the empirical analysis depicts possible "hub-and-spoke" structures of technology fields, as not all European regions exhibit a central position in co-patenting networks. In addition, the study analyzes whether or not some regions represent "multi-technology hubs" due to their diversified co-patenting activity and research strength in several technology fields.

The fifth chapter represents the third empirical part of the study and focuses on the European growth process and income disparities at the regional level between 1995 and 2006. Section 5.1 introduces the chapter and focuses on research gaps and the central issues with regard to regional inequality, convergence and growth studies. The subsequent section 5.2 then offers an overview of the database which was employed, containing regional data and the spatial classification systems. The first step involves an empirical analysis of European regional income disparities at the regional level (section 5.3). The analysis centers on the distributional dynamics of GDP per capita (PPP) across European regions and asks whether or not European regional disparities in GDP per capita are generally decreasing since the 1990s. Moreover, the analysis decomposes overall regional income disparity into within-subgroup and between-subgroup disparity, indicating that income inequality originates from income disparity across regions within countries and income disparity between countries. Accordingly, the empirical analysis examines whether or not convergence of per capita income levels is mainly a national phenomenon. Moreover, Gini indices and generalized entropy measures at the regional level are applied. Furthermore, the analysis examines whether or not the EU-15 countries exhibit similar trends in income disparities when compared to the NMS. In a second step, the analysis emphasizes cross-sectional unconditional and conditional pan-European growth regressions for EU-15 and NMS regions (section 5.4). The empirical analysis examines whether or not regional growth is differing with regard to the level of regional technological knowledge and research activity (measured by EPO patenting activity), and the regional settlement structure (capital regions, metropolitan, urban, intermediate and rural areas). This analysis addresses whether or not capital regions and urban and metropolitan regions exhibit higher growth rates of GDP per capita between 1995 and 2006. As spatial dependence could potentially be an issue, meaning that regional growth could be affected by neighboring regions' growth processes, tools of spatial econometrics, e.g., spatial maximum likelihood estimations, are additionally applied.

The sixth chapter comprises a summary of the empirical results of the previous chapters. It offers concluding remarks, a discussion of technical issues, drawbacks and shortcomings and some normative aspects with regard to the geographic distribution of European research activity, research clustering, inter-regional co-patenting networks and growth differences relating to the regional settlement structure and regional patenting activity. Some policy-related conclusions are elaborated on with regard to the observed regional patterns and structural dynamics of research clustering and inter-regional co-patenting networks in the ERA. Finally, the chapter offers a discussion of methodological and data related shortcomings of the presented empirical analyses and elaborates on issues of data availability and the direction of future research in a pan-European context.