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The Regional Geography of Corporate Patenting in Information and Communications Technology (ICT): Domestic and Foreign Dimensions

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SANTANGELO G. D. (2002) The regional geography of corporate patenting in information and communications technology (ICT): domestic and foreign dimensions, *Reg. Studies* **36**, 495–514. In the new techno-socio-economic conditions, characterized by an increasing reduction of temporal and spatial barriers, and further globalization of economic activity, paradoxically geography seems to matter more than ever before. This particularly applies to science-based industries (e.g. information and communications technology – ICT), where links between corporate competitors, and firm–university and user–producer relationships are crucial in the development and adoption of new flexible technologies. Using US patents granted to the largest European electronic firms, this paper looks at the interplay between the patenting by domestic and European foreign electronics companies of research and development carried out in ICT fields in German, UK and Italian regions. The findings suggest that patenting is attracted to existing areas of industrial strength taking a form of cumulative causation. Nonetheless, policy measures may be successful in reversing the trend.

Information and communications technology Multinational corporations Research and development
European regions

SANTANGELO G. D. (2002) La géographie régionale de la demande de brevets par les entreprises dans le domaine de la Technologie de l'Information et de la Communication (TIC): les dimensions nationale et internationale, *Reg. Studies* **36**, 495–514. Sous de nouvelles conditions techno- et socio-économiques, caractérisées par la poursuite du démantèlement des barrières temporelles et géographiques et par la mondialisation accrue de l'activité économique, il semble que paradoxalement la géographie importe plus que jamais. Cela s'applique en particulier aux industries basées sur la science (à savoir, la technologie de l'information et de la communication – la TIC), où les liens entre les concurrents, et les rapports entre les entreprises et les universités, et entre les utilisateurs et les producteurs, sont essentiels au développement et à l'adoption des nouvelles technologies flexibles. A partir des brevets américains accordés aux plus grandes entreprises européennes du secteur de l'électronique, cet article cherche à examiner l'interaction de la demande de brevets par les entreprises étrangères nationales et européennes du secteur de l'électronique pour ce qui est de la recherche et développement effectuée dans le domaine de la TIC dans les régions en Allemagne, au Royaume-Uni et en Italie. Les résultats laissent supposer que la demande de brevets se concentre sur des activités industrielles puissantes existantes et s'explique par une sorte de causalité cumulée. Toujours est-il que la politique pourrait faire marche arrière.

Technologie de l'Information et de la Communication
Entreprises multinationales
Recherche et Développement Régions européennes

SANTANGELO G. D. (2002) Die regionale Verteilung korporativer Patentierungsaufträge in der Informations-und Kommunikationstechnologie (ICT), *Reg. Studies* **36**, 495–514. In den neuen technisch-sozialwirtschaftlichen Verhältnissen, die durch zunehmenden Abbau zeitlicher und räumlicher Schranken sowie durch weitere Giobalisierung wirtschaftlicher Betätigung charaktrisiert wird, scheint der Verteilung paradoxerweise größere Bedeutung denn je zuvor zuzukommen. Dies gilt besonders für wissenschaftlich fundierte Industrien (z.B. Informations-und Kommunikationstechnologie (ICT), wo Verknüpfungen zwischen korporativen Konkurrenten und Beziehungen zwischen Firmen und Universitäten, sowie Anwendern und Herstellern für Entwicklung und Übernahme neuer, flexibler Technologien entscheidend sind. Mit Hilfe von US Patenten, die den größten Elektrofirmen Europas erteilt wurden, betrachtet dieser Aufsatz das Zusammenspiel von Patentierungen durch inländische und ausländische europäische Elektronikfirmen für Forschung und Entwicklung, die auf dem Gebiet der ICT in deutschen, britischen und italienischen Regionen durchgeführt wird. Die Befunde legen nahe, daß Patentierungsinstitute von bereits bestehenden Industriegebieten angezogen werden, und damit eine Form kumulativer Kausalität annehmen. Nichtsdestoweniger könnten Bestrebungen, diesen Kreislauf in entgegengestzte Richtung zu lenken, erfolgreich sein.

Informations-und Kommunikationstechnologie
Multinationale Korporationen
Forschung und Entwicklung Europäische Regionen

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INTRODUCTION

This paper investigates the interplay between domestic and European foreign electronics firms in European regional development of information and communications technology (ICT) research activity in order to develop a taxonomy of regional models of ICT technological development.

Although great emphasis has been placed on the role of geography in explaining local and corporate innovation in the US regions (e.g. JAFFE *et al.*, 1993), the European regional dimension has begun to be explored only recently (e.g. CANIËLS, 1998; CANTWELL and IAMMARINO, 1998, 2000). In the European context, empirical studies at a country level have shown high heterogeneity in the accumulation and diffusion of technology (ARCHIBUGI and PIANTA, 1992). However, the situation at a regional level is even more heterogeneous in terms of both GDP growth (FAGERBERG, 1996; IAMMARINO and SANTANGELO, 2000) and technology development (CANTWELL and IAMMARINO, 1998, 2000). This heterogeneity – understood in terms of great cross-regional differences reflecting uneven socio-economic situations – is the result of cumulative causation mechanisms, which maintain and reproduce geographical hierarchies over time discriminating between *higher* and *lower* order locations.

In the new techno-socio-economic conditions, the R&D activity of multinational corporations (MNCs) plays a great role in shaping regional hierarchies across countries. The new techno-socio-economic conditions, characterized by the globalization of economic activity and fast pace of technological change, have emphasized the importance of internal locations competing to attract MNCs' quality investments. In this sense, national/regional systems of innovation do not undermine the globalization process in terms of the production and diffusion of technology but rather reinforce it (e.g. ARCHIBUGI and MICHIE, 1995). The higher the level of corporate internationalization, the stronger the linkages the firm establishes with the local system (LOINGER and PEYRACHE, 1988). Besides the flexibility in promoting the development of just-in-time distribution and more flexible manufacturing systems, the widespread application of ICT allows MNCs to establish intra- and inter-firm network linkages enabling them to outsource knowledge from different internal locations. Therefore, the spatial organization of multinational corporations is shaped by different internal organization forces. Agglomeration economies, characterized by co-located firms operating in different sectors, appear to provide multinationals with locational advantages that go well beyond the mere sectoral specialization of the local centre and embrace the overall value-added embodied in the domestic environment.

Similarly, regional growth and development depend upon the local presence of MNC activities. The creation of local conditions appealing to MNCs is the challenge for an effective regional policy aimed at local growth as well as development. In fact, if geographical hierarchies appear to be stable over time, they can be reversed with the adoption of dynamic regional policies, aiming at long-run sustainable growth rather than at short-run solutions to local socio-economic problems.

Thus, in an overall economic context of increasing globalization of economic activity and fast technological change, a regionally-based analysis seems to make more sense than ever before in order to understand the factors driving spatial concentration of corporate R&D as well as cross-border regional hierarchies. The presence (absence) of a dynamic local environment starts up *virtuous* (*vicious*) cycles, which are reproduced over time through a cumulative causation mechanism (unless the cycle is somehow reversed as discussed below).

Using US patents granted to the largest European electronics firms, this paper seeks to analyse the interplay of corporate European foreign and indigenous innovative activity in ICT in German, UK and Italian regions. ICT technological activity is here understood in terms of communications and computing technologies as specified in detail below. The distinctiveness of these sectors lies in their fast growing character, increasing pervasiveness in a wide range of production processes and their context-dependence in spatial terms. The paper is organized in five main sections. The following section discusses the significance of the regional dimension in the new techno-socio-economic conditions. The third section throws some light on the statistical methodology adopted as well as on the regional patent data currently available in the Reading database. The fourth section is devoted to the analysis of the empirical evidence. A few conclusions are drawn in the final section.

THE SIGNIFICANCE OF THE REGIONAL DIMENSION

In the new techno-socio-economic conditions, characterized by an increasing reduction of temporal and spatial barriers, and further globalization of economic activity, paradoxically geography seems to matter more than ever before. This seems to be mainly due to the path-dependent character of knowledge creation and learning, which makes local systems (national/regional) key sources of competitiveness in the context of *techno-globalism* (ARCHIBUGI and MICHIE, 1995).[1]

Although globalization has led to more open technological systems, the local dimension still plays an important role when looking at the technological and geographical diversification of multinationals' R&D facilities. As a result of the rediscovery of competencies as determinants of economic performance, the importance of proximity in generating interactive learning

(MASKELL and MALMBERG, 1999) as well as the consequent need to integrate localized capabilities within global networks have been recognized (COHENDET *et al.*, 1999). Therefore, the increasing globalization of economic activity has emphasized the importance of clusters of innovative local centres accumulating over time new knowledge embodied in best practices (SÖLVELL and BIRKINSHAW, 2000). In this sense, the knowledge-driven economy has witnessed the rise of regional territorial units as the key dimension of the global development of technology.

However, sceptical views (e.g. LOVERING, 1999) about the phenomenon of 'new regionalism' exist. Without denying the relevance of regional level analyses as such, the critiques are mainly directed to the causal approach, and in particular on its neglect of the national dimension and its emphasis on a regional approach without much understanding of the underlying causes of the phenomenon. Therefore, this view calls for a more cautious evaluation of the impact of foreign direct investment (FDI) on local systems. In this light, it should be recognized that the production of basic (or tacit) knowledge is highly concentrated, while its combinations and adaptation are more spread out and closer to users. The high costs of codification (DASGUPTA and DAVID, 1994) do not make it profitable for the firm to adopt a dispersed geographical strategy of basic knowledge production. Although the development of ICT has promoted a growing geographical dispersion of intra-firm networks, the creation of more complex kinds of technological innovation remains largely concentrated in a few centres of excellence, and more highly dependent upon the localized contexts provided by these centres (CANTWELL and SANTANGELO, 1999). Conversely, less complex and more codifiable knowledge can be easily transferred at much lower costs (*ibid.*). Thus, the distinction between tacit and codified knowledge calls for an economic analysis more concerned with the typology of FDI in order to assess their impacts on the territory of a region.

In science-based industries (e.g. ICT), links between corporate competitors, and firm–university and user–producer relationships, are crucial in the development and adoption of new flexible technologies (SWANN and PREVEZER, 1996). Diverging over the starting-point (whether it be the 'global' – the MNC, or the 'local' – the territorial unit), all theoretical lines developing from new economic geography models underline the importance of the localized higher value-added in explaining economic agglomeration and performance. Local networks and infrastructures are likely to promote the potential for knowledge creation and learning. Manufacturing, human, physical, communications and industrial governance infrastructures (FLORIDA, 1995) are key factors defining the 'knowledge-based' or 'learning' region, able to maintain its sustainable advantage over time. The success of the 'learning region' relies on capabilities to mobilize technical resources, knowledge and other inputs essential to innovation (AMIN *et al.*, 1994).

The local ability to develop an entrepreneurial environment through expertise accumulation follows strong path-dependent trajectories. In this sense, the pervasive character of ICT is provoking a transformation in urban and regional systems by generating a new network model involving *core regions* and *locational economies models*,[2] and neglecting peripheral areas (MALECKI, 1994). This new network model is reproduced over time through *vicious* and *virtuous* circles as a result of the path-dependent character of expertise accumulation. Therefore, as technological change affects not only the long term growth of the economy, but also the spatial distribution of economic activity, a concentration phenomenon has emerged as has a consequent geographical hierarchy of regional centres reinforced over time by the interplay between indigenous agglomeration and the location of corporate expertise. This has created a paradox in contemporary Europe, where an acceleration of processes of innovation coexists with mass unemployment and widespread social exclusion (ASHEIM and DUNFORD, 1997). In this geographically polarized context, the crucial role of innovation in boosting local economies has been also recognized at an institutional level by the European Union (EU), whose regional policy, articulated through the Structural Funds, aims at economic and social cohesion across the Union.

STATISTICAL METHODOLOGY

The empirical evidence provided in this paper is based upon US patents granted to the largest European electronics firms in the US between 1969 and 1995. Here patents are understood as a proxy for learning activity associated with the take-up of new products and processes in technologically advanced production facilities, and not for the creation of new knowledge as such. Although basic research may not be directly patented, the R&D output that patents capture is the new knowledge associated with the establishment of tacit capability, which applies such knowledge and makes it operational.

A discussion on the *use* and *abuse* of patent statistics as a measure of innovative activity is beyond the scope of this study (see e.g. PAVITT, 1988). Nonetheless, it should be mentioned that patents allow one to analyse technological activity by providing long and complete time-series, and information at detailed levels of sectoral disaggregation. If the former enable one to draw detailed pictures of the historical development of technological activity, the latter makes feasible the investigation of its rate and direction. Other important information provided by the patent document, which is of immediate interest for this study, concerns the distinction between the location where the R&D activity was carried out and the location of the actor

(individual or corporate) to which the patent was granted. On these grounds, it is possible to conduct analyses concerning the spatial aspects of technological innovation. Besides the advantages of using patent statistics, a number of drawbacks can be identified. In adopting and reading patent data results, it should be borne in mind that many inventions are never patented, that not all inventions are technologically patentable, and that not all inventions which are patented become innovations.

The patent data adopted in this study are drawn from the University of Reading database. Using a classification scheme derived from the patent class system of the US Patent and Trademark Office (USPTO), each patent is classified into one of the 399 original patent classes. In the Reading database, those patent classes have been allocated to one of 56 technological groups according to related technological fields/sectors; six of the 56 technological sectors comprise the main field of ICT.[3] Therefore, the sample refers to all European firms classified in the broad electronics corporate industrial group in the database held at the University of Reading (see Table 1). The broad electronics industrial group includes 'electrical equipment' (communications) and 'office equipment' (computing) industries (see Table 2).

Recently, the Reading database has been regionalized. The sub-national entities identified correspond to the units classified by the European Nomenclature of Territorial Units for Statistics (NUTS) established by Eurostat. The regionalization of the Reading patent database has been carried out by attributing a NUTS code (as precise as possible as far as the first three NUTS levels are concerned) to each patent over the period 1969–95.

In this exercise, the geographical distribution of European electronics corporate patenting activity in the ICT technological sectors is investigated in German, UK and Italian regions for which regionalized patent data are currently available in the Reading database. For each of these three countries, the sub-national entities identified correspond to territorial units as classified by the NUTS nomenclature. In order to ensure as much comparability as possible, the NUTS 1 level is used to identify German and UK regions while, as far as Italian regions are concerned, the NUTS 2 level is adopted. The 16 German *Länder*, the 11 UK *standard regions* and the 20 Italian *regioni* that are identified as a result of this choice seem to guarantee comparability as far as innovative activity is concerned (see Table 3).[4]

Table 1. List of the ICT technological sectors, 1969–95

Telecommunications
Other electrical communication systems
Special radio systems
Image and sound equipment
Semiconductors
Office equipment and data processing systems

Table 2. List of companies in the sample (nationality of ownership in brackets)

ABB (Switzerland)	LM Ericcson (Sweden)
AEG Telefunken (Germany)	Nixdorf Computer (Germany)
ASEA (Sweden)	Olivetti (Italy)
BICC (UK)	Philips (The Netherlands)
Bosch-Siemens-Hausgeräte (Germany)	Plessey (UK)
Brown Boveri (Switzerland)	Racal Electronics (UK)
CGE (France)	Sagem (France)
CII-Honeywell (France)	Siemens (Germany)
Electrolux (Sweden)	STC (UK)
General Electric Co. (UK)	Thomson-Brandt (France)
ICL (UK)	Thorn EMI (UK)
	Zanussi (Italy)

THE REGIONAL DIMENSION: THE INTERPLAY OF DOMESTIC AND FOREIGN FIRMS

Within each of the three countries under analysis, in each region the patenting activity of domestic and European foreign electronics firms in each of the six ICT sectors was distinguished as reported in Tables 4, 5 and 6, which also illustrate the share of European foreign companies in each of the ICT sectors relative to the European electronics corporate total in the region and in the sector in question.

In order to find a statistically supported classification, in the first instance, for each country we ran a three-way ANOVA – grouping the observations according to European/domestic, region and ICT field – the ultimate aim being to identify significant main effects

Table 3. Regional locations where European-owned research activity in ICT technological sectors is carried out, 1969–95

German *Länder* (NUTS 1)	Italian *regioni* (NUTS 2)	UK standard regions (NUTS 1)
Baden-Württemberg	Calabria	East Anglia
Bayern	Campania	East Midlands
Berlin	Emilia Romagna	North
Brandenburg	Friuli-Venezia Giulia	North West
Bremen	Lazio	Scotland
Hamburg	Liguria	South East
Hessen	Lombardia	South West
Mecklenburg-Vorpommern	Piemonte	Wales
Niedersachsen	Toscana	West Midlands
Nordrhein-Westfalen	Sicilia	Yorkshire and Humberside
Rheinland-Pfalz		
Sachsen		
Sachsen-Anhalt		
Schleswig-Holstein		
Thuringen		

Table 4. Distribution of US patents in ICT sectors for R&D activity located in German regions, by domestic and European foreign electronics firms: 1969–95

German regions (NUTS 1)	ICT sectors	No. of patents by German electronics firms	No. of patents by European electronics firms	Share of European foreign electronics firms (%)
Baden-Württemberg	Telecommunications	29	70	57·1
	Other electrical communication systems	24	10	31·3
	Special radio systems	15	1	14·3
	Image and sound equipment	7	47	53·3
	Semiconductors	53	16	29·4
	Office equipment and data processing systems	32	107	59·4
Bayern	Telecommunications	747	114	30·4
	Other electrical communication systems	246	18	21·6
	Special radio systems	79	2	8·3
	Image and sound equipment	192	29	33·3
	Semiconductors	505	8	13·5
	Office equipment and data processing systems	627	39	20·8
Niedersachsen	Telecommunications	61	6	26·7
	Other electrical communication systems	24	7	31·3
	Special radio systems	2	1	33·3
	Image and sound equipment	31	22	47·4
	Semiconductors	4	4	50·0
	Office equipment and data processing systems	50	15	34·8
Schleswig-Holstein	Telecommunications	3	12	60·0
	Other electrical communication systems	9	6	37·5
	Special radio systems	1	4	66·7
	Image and sound equipment	84	26	50·0
	Semiconductors	1	16	85·7
	Office equipment and data processing systems	15	26	38·5
Hessen	Telecommunications	15	8	41·7
	Other electrical communication systems	6	2	28·6
	Special radio systems	1	0	0·0
	Image and sound equipment	5	13	37·5
	Semiconductors	8	7	14·3
	Office equipment and data processing systems	10	52	62·5
Nordrhein-Westfalen	Telecommunications	27	12	30·8
	Other electrical communication systems	10	1	14·3
	Special radio systems	4	0	0·0
	Image and sound equipment	11	12	50·0
	Semiconductors	16	6	36·4
	Office equipment and data processing systems	40	15	25·0
Rheinland-Pfalz	Telecommunications	15	2	20·0
	Other electrical communication systems	3	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	3	3	50·0
	Semiconductors	0	10	100·0
	Office equipment and data processing systems	2	2	66·7
Hamburg	Telecommunications	1	23	50·0
	Other electrical communication systems	0	17	100·0
	Special radio systems	0	0	0·0
	Image and sound equipment	2	56	50·0
	Semiconductors	0	24	100·0
	Office equipment and data processing systems	0	50	100·0
Berlin	Telecommunications	8	0	0·0
	Other electrical communication systems	6	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	3	0	0·0
	Semiconductors	5	0	0·0
	Office equipment and data processing systems	24	19	25·0
Brandenburg	Telecommunications	0	1	100·0
	Other electrical communication systems	1	0	0·0
	Special radio systems	1	0	0·0
	Image and sound equipment	1	2	50·0
	Semiconductors	0	1	100·0
	Office equipment and data processing systems	0	0	0·0

Table 4. Continued

German regions (NUTS 1)	ICT sectors	No. of patents by German electronics firms	No. of patents by European electronics firms	Share of European foreign electronics firms (%)
Bremen	Telecommunications	0	4	100·0
	Other electrical communication systems	0	5	100·0
	Special radio systems	0	1	100·0
	Image and sound equipment	0	3	100·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	0	1	100·0
Mecklenburg-Vorpommern	Telecommunications	1	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	3	1	0·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	0	0	0·0
Sachsen	Telecommunications	0	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	1	0	0·0
	Semiconductors	1	0	0·0
	Office equipment and data processing systems	1	0	0·0
Sachsen-Anhalt	Telecommunications	2	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	2	0	0·0
Thüringen	Telecommunications	3	0	0·0
	Other electrical communication systems	1	0	0·0
	Special radio systems	1	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	2	1	0·0

of specific factors (namely FIRM, REGION and ICT field respectively) impacting on electronics corporate patenting activity. The effects the analysis intends to capture are the presence of either European or domestic companies (FIRM), different level of regional attractiveness (REGION) and specific ICT sectoral patterns (ICT). This preliminary analysis provided an overview of the phenomenon under consideration. The results, reported in Tables 7, 8 and 9, show significant main effects for all factors except ICT, in the German and UK cases (Tables 7 and 8).

Both factors, FIRM and REGION, have an impact on the distribution of patents granted in electronics sectors in the context of the European electronics industry. Conversely, the differences between ICT fields do not account significantly for the variation in the patent distributions considered. Therefore, in both countries electronics corporate patenting may be explained by the presence of either European or domestic companies as well as by the different levels of regional attractiveness, but not by specific ICT sectoral patterns. Different results were obtained in the Italian case as shown in Table 9, where only the factor REGION (not the factor FIRM nor the factor ICT) was found to account significantly for the variation in the number of electronics corporate patents, implying that differences in regional attractiveness (rather than the presence of either European or domestic companies, and/or specific ICT sectoral patterns, on their own) explain the magnitude of corporate electronics patenting. However, due to the level of disaggregation of our data, no interaction effects between the three factors could be captured.[5] On the grounds of these results, the analysis proceeded by conducting a two-way procedure in order to investigate the existence of interaction effects between the factors found significant.[6] The results, which are reported in Tables 10, 11 and 12, show some interesting findings.

In Germany and the UK, the two main effects (FIRM and REGION) and the interaction effect were found to be statistically significant as illustrated in Tables 10 and 11. This means that electronics corporate patenting activity differs on average across regions suggesting different levels of regional attractiveness. Similarly, the patent distributions show a statistically significant variability between European and domestic firms. That is, European and domestic companies patent to different extents within Germany and the

Table 5. Distribution of US patents in ICT sectors for R&D activity located in the UK regions, by domestic and foreign electronics firm: 1969–95

UK regions (NUTS 1)	ICT sectors	No. of patents by UK electronics firms	No. of patents by non-UK electronics firms	Share of European foreign electronics firms (%)
South East	Telecommunications	191	67	26·0
	Other electrical communication systems	110	66	37·5
	Special radio systems	172	41	19·2
	Image and sound equipment	112	62	35·6
	Semiconductors	48	117	70·9
	Office equipment and data processing systems	219	58	20·9
East Anglia	Telecommunications	11	23	67·6
	Other electrical communication systems	0	6	100·0
	Special radio systems	3	2	40·0
	Image and sound equipment	0	22	100·0
	Semiconductors	4	5	55·6
	Office equipment and data processing systems	4	6	60·0
East Midlands	Telecommunications	28	1	3·4
	Other electrical communication systems	9	0	0·0
	Special radio systems	12	0	0·0
	Image and sound equipment	5	0	0·0
	Semiconductors	20	0	0·0
	Office equipment and data processing systems	27	0	0·0
South West	Telecommunications	53	7	11·7
	Other electrical communication systems	9	1	10·0
	Special radio systems	12	0	0·0
	Image and sound equipment	5	1	16·7
	Semiconductors	8	1	11·1
	Office equipment and data processing systems	35	0	0·0
West Midlands	Telecommunications	30	1	3·2
	Other electrical communication systems	11	1	8·3
	Special radio systems	2	0	0·0
	Image and sound equipment	2	1	33·3
	Semiconductors	13	1	7·1
	Office equipment and data processing systems	25	0	0·0
North West	Telecommunications	22	1	4·3
	Other electrical communication systems	24	1	4·0
	Special radio systems	2	0	0·0
	Image and sound equipment	3	1	25·0
	Semiconductors	7	11	61·1
	Office equipment and data processing systems	49	1	2·0
Wales	Telecommunications	6	1	14·3
	Other electrical communication systems	0	1	100·0
	Special radio systems	2	0	0·0
	Image and sound equipment	2	1	33·3
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	0	0	0·0
Scotland	Telecommunications	3	1	25·0
	Other electrical communication systems	6	0	0·0
	Special radio systems	2	0	0·0
	Image and sound equipment	1	0	0·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	6	0	0·0
North	Telecommunications	4	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	1	0	0·0
	Office equipment and data processing systems	2	0	0·0
Yorkshire and Humberside	Telecommunications	5	0	0·0
	Other electrical communication systems	3	1	25·0
	Special radio systems	1	0	0·0
	Image and sound equipment	1	1	50·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	3	0	0·0

Table 6. Distribution of US patents in ICT sectors for R&D activity located in Italian regions, by domestic and European electronics firm: 1969–95

Italian regions (NUTS 2)	ICT sectors	No. of patents by Italian electronics firms	No. of patents by European electronics firms	Share of European foreign electronics firms (%)
Lombardia	Telecommunications	1	17	80·0
	Other electrical communication systems	1	3	75·0
	Special radio systems	0	1	100·0
	Image and sound equipment	0	5	100·0
	Semiconductors	2	54	85·7
	Office equipment and data processing systems	14	57	90·9
Piemonte	Telecommunications	21	3	66·7
	Other electrical communication systems	23	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	13	2	66·7
	Semiconductors	1	1	50·0
	Office equipment and data processing systems	87	2	33·3
Lazio	Telecommunications	0	3	100·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	2	100·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	0	2	100·0
Friuli-Venezia Giulia	Telecommunications	0	0	
	Other electrical communication systems	1	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	3	0	0·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	3	0	0·0
Emilia Romagna	Telecommunications	0	1	100·0
	Other electrical communication systems	1	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	3	100·0
	Office equipment and data processing systems	5	0	0·0
Toscana	Telecommunications	1	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	1	0	0·0
	Semiconductors	0	2	100·0
	Office equipment and data processing systems	1	0	0·0
Liguria	Telecommunications	0	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	1	100·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	0	0·0
	Office equipment and data processing systems	0	0	0·0
Campania	Telecommunications	0	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	1	100·0
	Office equipment and data processing systems	0	0	0·0
Calabria	Telecommunications	0	0	0·0
	Other electrical communication systems	0	1	100·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	1	100·0
	Office equipment and data processing systems	0	0	0·0
Sicilia	Telecommunications	0	0	0·0
	Other electrical communication systems	0	0	0·0
	Special radio systems	0	0	0·0
	Image and sound equipment	0	0	0·0
	Semiconductors	0	12	100·0
	Office equipment and data processing systems	0	0	0·0

Table 7. Three-way ANOVA results for German regions[1]

	Sum of squares	df	Mean square	F	
Main effects (combined)	556,737·67	20	27,836·88	6·02	**
FIRM	25,134·05	1	25,134·05	5·43	*
ICT	28,522·58	5	5,704·52	1·23	
REGION	503,081·03	14	35,934·36	7·77	**
Model	556,737·67	20	27,836·88	6·02	**
Residual	735,393·28	159	4,625·11		
Total	1,292,130·95	179	7,218·61		

Notes: 1. Unique method: all effects entered simultaneously.
** significant at 1%.
* significant at 5%.

Table 8. Three-way ANOVA results for UK regions[1]

	Sum of squares	df	Mean square	F	
Main effects (combined)	117,934·43	15	7,862·30	20·6578777	**
FIRM	5,658·13	1	5,658·13	14·86652665	**
ICT	2,869·77	5	573·95	1·5080402	
REGION	109,406·53	9	12,156·28	31·94015975	**
Model	117,934·43	15	7,862·30	20·6578777	**
Residual	39,581·93	104	380·60		
Total	157,516·37	119	1,323·67		

Notes: 1. Unique method: all effects entered simultaneously.
** significant at 1%.

Table 9. Three-way ANOVA results for Italian regions[1]

	Sum of squares	df	Mean square	F	
Main effects (combined)	3,856·77	15	257·12	2·49	**
FIRM	1·72	1	1·72	0·02	
ICT	909·82	5	181·96	1·76	
REGION	2,937·41	9	326·38	3·16	**
Model	3,856·77	15	257·12	2·49	**
Residual	10,749·82	104	103·36		
Total	14,606·59	119	122·74		

Notes: 1. Unique method: all effects entered simultaneously.
** significant at 1%.
* significant at 5%.

Table 10. Two-way ANOVA results for German regions[1]

	Sum of squares	df	Mean square	F	
Main effects (combined)	528,215·08	15	35,214·34	13·680	**
FIRM	25,134·05	1	25,134·05	9·764	**
REGION	503,081·03	14	35,934·36	13·960	**
2-way interactions FIRM*REGION	377,801·70	14	26,985·84	10·484	**
Model	906,016·78	29	31,241·96	12·137	**
Residual	386,114·17	150	2,574·09		
Total	1,292,130·95	179	7,218·61		

Notes: 1. Unique method: all effects entered simultaneously.
** significant at 1%.

UK. However, the most interesting result is provided by the significance of the interaction effect, which can be interpreted as the combined effect of regional attractiveness and the presence of either European or domestic companies as shown in Figs. 1 and 2.

In the Italian case, as expected, the REGION effect (but not the FIRM effect) was found to be significant (Table 12) confirming the results of the three-way ANOVA. Yet, in this case the most interesting result is provided by the statistically significant interaction effect. This seems to suggest that, although the factor REGION (among those identified) accounts for most

Table 11. *Two-way ANOVA results for UK regions*[1]

	Sum of squares	df	Mean square	F	
Main effects (combined)	115,064·67	10	11,506·00	40·22	**
FIRM	5,658·13	1	5,658·13	19·78	**
REGION	109,406·53	9	12,156·28	42·49	**
2-way interactions FIRM*REGION	13,842·03	9	1,538·00	5·38	**
Model	128,906·70	19	6,784·56	23·71	**
Residual	28,609·67	100	286·10		
Total	157,516·37	119	1,323·67		

Notes: 1. Unique method: all effects entered simultaneously.
** significant at 1%.

Table 12. *Two-way ANOVA results for Italian regions*[1]

	Sum of squares	df	Mean square	F	
Main effects (combined)	3,317·19	10	331·719	3·68	**
FIRM	3,308·19	9	367·577	4·07	
REGION	0·83	1	0·831	0·01	**
2-way interactions FIRM*REGION	2,636·63	9	292·959	3·25	**
Model	5,583·59	19	293·873	3·26	**
Residual	9,023·00	100	90·230		
Total	14,606·59	119	122·744		

Notes: 1. Unique method: all effects entered simultaneously.
** significant at 1%.

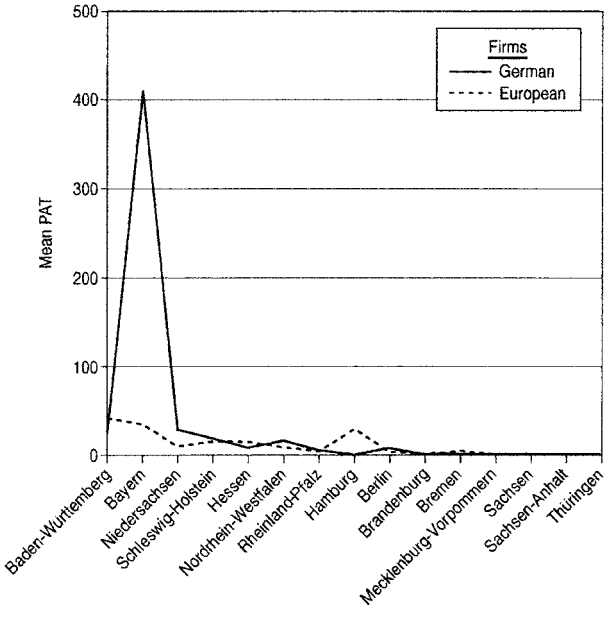

Fig. 1. *Means of patents, by German region and group of firms*

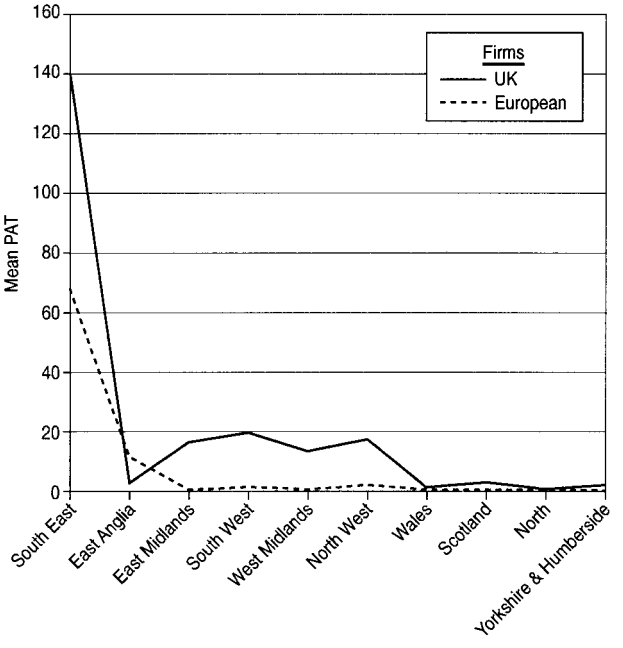

Fig. 2. *Means of patents, by UK region and group of firms*

of the variation in the patent distribution, in Italy there is also a significant combined effect of regional attractiveness and presence of either European or domestic companies. That is, the pattern across regions differs significantly according to whether one looks at domestic or European firms. Graphically, a clear example is the 'inversity' between Lombardia and Piemonte shown in Fig. 3.

As anticipated, the ANOVA results are plotted in Figs. 1, 2 and 3, which report the means of ICT patents for each region and for the two groups of firms (whether European or domestic). On these grounds, within each national context, regions were grouped into broad categories. In discussing these categories, consideration has been given to Tables 4, 5 and 6 as well as to Figs 4, 5, 7, 8, 9 and 10, where for each of the three sub-periods (1969–77, 1978–86 and 1987–95) the share of research activity carried out in ICT

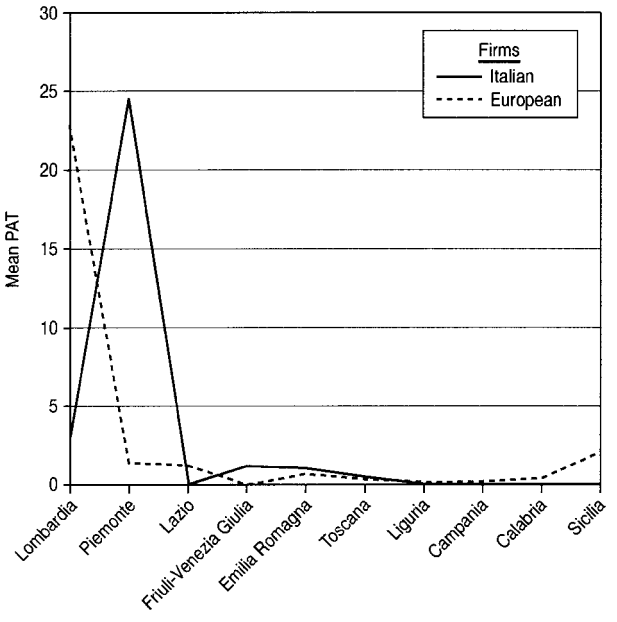

Fig. 3. *Means of patents, by Italian region and group of firms*

fields by domestic and European firms in each of the German, UK and Italian regions relative to the national domestic and European total respectively is reported in order to capture dynamic aspects of the phenomenon under analysis. Moreover, attempts have been made to account for the overall local economic structure as well as for the geography of the region, although this classification is mainly based on the industry under analysis. Each category is, then, defined by taking into account country-specific factors (e.g. major historical events – as in the German case; relevant changes in national/regional development polices – such as the establishment of the Development Agencies in the UK or the shift in the policy approach with respect to the Mezzogiorno issue in the case of Italy, etc.).

The German Länder

On the basis of the two-way ANOVA results plotted in Fig. 1, German *Länder* were grouped into six categories:

- regions attracting (to different extents) a great portion of patents from both European and domestic electronics companies: *Baden-Württemberg* and *Bayern* – Category 1
- regions attracting large (although more limited than the previous category) European and domestic research: *Niedersachsen* and *Schleswig-Holstein* – Category 2
- regions hosting a balanced presence of European and domestic firms: *Hessen*, *Nordrhein-Westfalen* and *Rheinland-Pfalz* – Category 3
- regions showing a concentration of European ICT patents: *Hamburg* – Category 4
- regions attracting limited portions of domestic and European R&D in ICT: *Berlin* and *Brandenburg* – Category 5
- all other regions, which do not show any or any significant presence of foreign and domestic research in ICT relative to all other regions – Category 6.[7]

In *Category 1*, Baden-Württemberg and Bayern are identified as *regional cores* in the development of ICT technology. In fact, if the picture emerging from Fig. 1 shows a great concentration of European and domestic patents in the overall period 1969–95, the upward trend in attracting larger and larger numbers of European and domestic ICT patents over time is confirmed in Figs. 4 and 5 (the decline in the number of German R&D laboratories located in Baden-Württemberg between the first and second sub-period is, in fact, partially recovered in 1987–95).

The choice of developing ICT technology in these regions is likely to go beyond the mere advantage of local companies in the technology in question.[8] Rather, the concentration of ICT R&D in these regions may be due to agglomeration economies stemming from the strong educational tradition embedded in several old universities, together with public policy support for a wide range of training and technical initiatives as well as to the location in the region of a group of large firms (e.g. Daimler-Benz, Bosch, Porsche and SEL), some of which are world leaders in specialized niches (MARSHALL, 1990). All these elements seem to frame the successful economic performance of these *Länder*, defined in the literature as having strong regional systems of innovation (*ibid.*). In fact, the dynamic regional environment attracts corporate development of core technologies (such as ICT), characterized by a high context-dependency. In turn, this reproduces and amplifies the overall local value-added, thus reinforcing agglomeration through *virtuous* circles. The reinforcement of this position over time may suggest that domestic and foreign corporate patenting activity in Baden-Württemberg and Bayern is due to the overall economic and social structure of these regions, which are among the most dynamic centres in Europe (EUROPEAN COMMUNITIES, 1993a).

Category 2 refers to Niedersachsen and Schleswig-Holstein. These *Länder* host large portions of domestic and European electronics R&D (Fig. 1). Nonetheless, substantial differences exist between Niedersachsen and Schleswig-Holstein, and Baden-Württemberg and Bayern. In fact, in the regions in question the magnitude of European and domestic R&D (although consistent within the national context) is far more limited than in the locations classified in Category 1. In terms of economic structure, local expertise is highly concentrated in specific industrial sectors such as the motor industry (in Niedersachsen) and 'ship, aviation and aerospace' (in Schleswig-Holstein) (*ibid.*). Thus, it may well be the case that the competitive advantage of

German companies in these sectors attracts European corporations seeking new technological applications of ICT. In a dynamic perspective, this is confirmed by the rise in the number of European patents in Niedersachsen and by a rationalization in Schleswig-Holstein against the fluctuations of German patents over time (Figs. 4 and 5). As discussed by TEECE, 1998, a core feature of the current techno-socio-economic paradigm is the combination of previously separated technologies as shown by the birth of new streams of technological development such as mechatronics arising from the fusion of mechanical industries and electronics. In passing, although both European and German firms are active in all ICT sectors (to a lesser extent than in Baden-Württemberg and Bayern), patterns of sectoral overlapping are clearly recorded (e.g. telecommunications, image and sound equipment, and office equipment and data processing systems in Niedersachsen, and image and sound equipment, and office equipment and data processing systems in Schleswig-Holstein) (Table 1). Therefore, given their overall economic structure together with the ICT patterns revealed by the analysis, these *Länder* may be defined as rising *regional cores*.

Category 3 concerns Hessen, Nordrhein-Westfalen and Rheinland-Pfalz, hosting a balanced presence of European and domestic R&D (Fig. 1). The dynamic framework set in Fig. 5 also reveals a growing attractiveness of these regions as illustrated by the increase in European patenting over time (the fluctuations recorded in Nordrhein-Westfalen between 1969–77 and 1978–86 are, in fact, fully stabilized in the last sub-period under analysis) as well as a growth in German R&D from the first to the third sub-period (with a slight slowdown in Rheinland-Pfalz). It can also be noted that, in terms of ICT sectors, these *Länder* seem to reproduce the German model as illustrated in Fig. 6.

Fig. 6 shows the share of research activity carried out in each ICT sector by European-owned electronics companies in Germany, UK and Italy relative to Europe. In all three countries, local capabilities and consequent local competitive advantage in specific ICT sectors seem to attract foreign companies.[9] As far as Germany is concerned, the country appears to be an appealing location for European electronics companies in telecommunications, image and sound equipment and office equipment and data processing systems. Similarly, it is worth noting that these ICT sectors are the areas of expertise of Siemens, which took over Nixdorf Computer within the time period covered. In Hessen, Nordrhein-Westfalen and Rheinland-Pfalz, telecommunications, image and sound equipment, and computing sectors are the fields in which the research laboratories of the European electronics firms do mainly research (Table 4). The national weakness in attracting European foreign R&D in 'special radio systems' (Fig. 6) is also confirmed in all three regions. As shown in Table 4, in this sector patenting activity is either absorbed completely by indigenous firms (this is the case in Hessen and Nordrhein-Westfalen) or virtu-

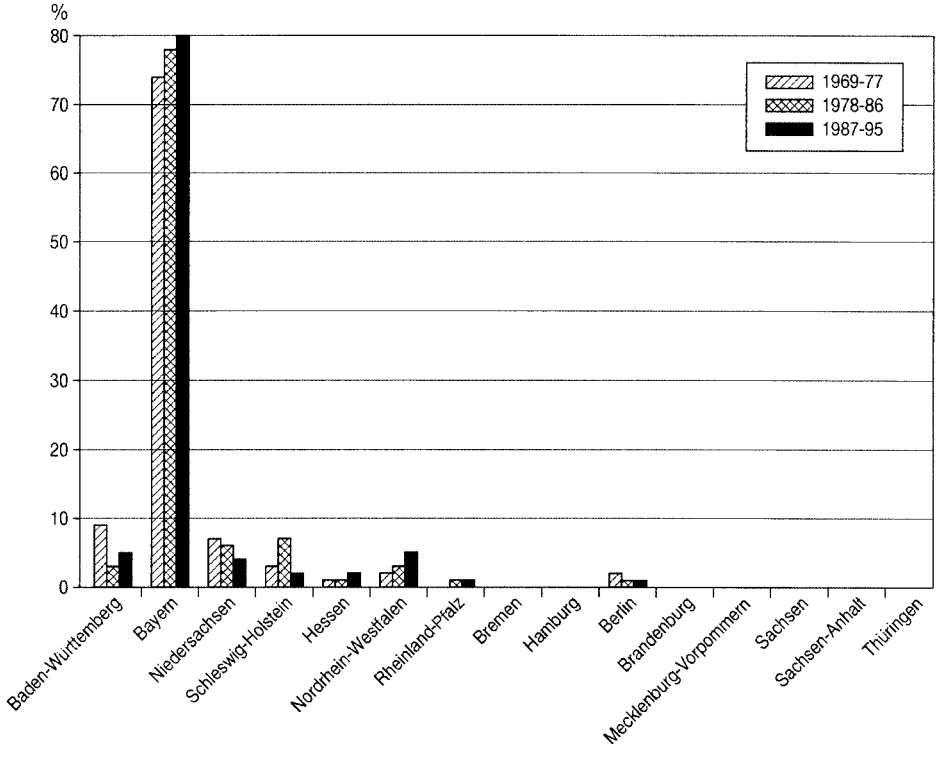

Fig. 4. Share of research activity carried out in ICT fields by German electronics firms located in German regions, relative to the national domestic total, by period

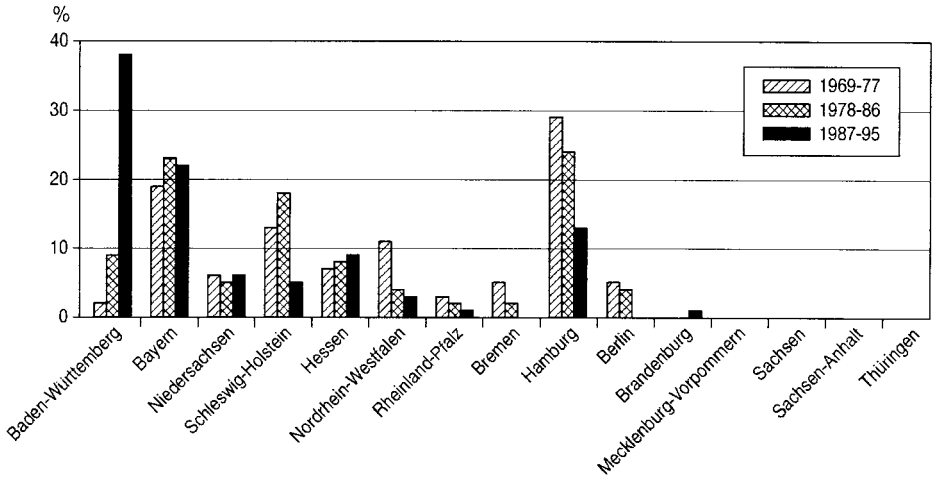

Fig. 5. *Share of research activity carried out in ICT fields by European foreign electronics firms located in German regions, relative to the national European total, by period*

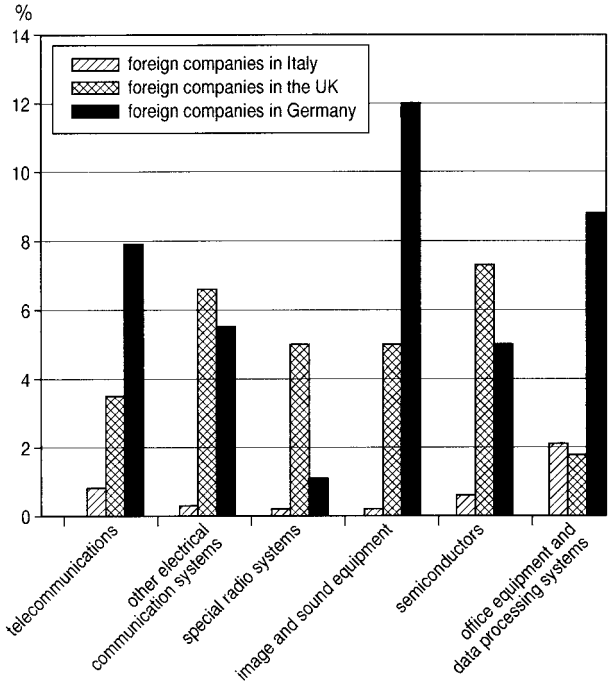

Fig. 6. *Share of research activity carried out in ICT fields by European foreign electronics firms located in the three countries under analysis, relative to Europe as a whole, 1969–95*

ally absent (as in Rheinland-Pfalz). Moreover, the overall pattern shown by these *Länder* in ICT technologies seems to find a certain correspondence in the regional industrial structures developing around the chemical sector (EUROPEAN COMMUNITIES, 1993a; CANTWELL and NOONAN, 2001). It is worth noting that, historically, Germany has shown a great comparative advantage in the chemical sectors (ARCHIBUGI and PIANTA, 1992). In this sense, it may be argued that Hessen, Nordrhein-Westfalen and Rheinland-Pfalz reproduce the German national system of innovation characterized by a competitive strength in chemicals and related sectors and in selected ICT fields. This classifies the regions as models of *locational economies*.

Hamburg is classified in *Category 4* as showing a relative concentration of European electronics patenting activity, but an almost complete lack of indigenous activity. The restructuring of the *Länder*'s economy and the unification of Germany in the early 1990s may provide some explanation for this pattern. The regional economy is shifting 'from ship to chip' (EUROPEAN COMMUNITIES, 1993a). This structural conversion to high technology sectors has been supported by the EU Structural Funds as confirmed by the inclusion of Hamburg under Objectives 3 and 4 of the Funds (see Table 13) (EUROPEAN COMMUNITIES, 1997a).

However, if the industrial conversion of the industry structure may explain the concentration of European electronics R&D in the regions under analysis, the unification of the German state in 1990 and the consequent opening up of new markets in Eastern Europe should be also taken into account when evaluating the location strategy of European corporations within Germany. In fact, Hamburg has been defined as the 'gateway to the new markets' (EUROPEAN COMMUNITIES, 1993a). Although this regional locational advantage has increasingly attracted foreign companies over time, it has not made the *Länder* more appealing to domestic firms (Figs. 4 and 5). The weak presence of indigenous patenting in ICT sectors in this *Land* may confirm the argument that German companies with headquarters in South Germany do little in these regional locations, while companies coming from nearby European locations do more. In fact, German companies do not seem to have relocated their innovative activities as a result of the opening of the eastern European markets as they can easily move towards the new markets from their current positions.

Category 5 refers to Berlin and Brandenburg, targeted by German companies mainly and to a more limited

Table 13. *Objectives of EU regional policy implemented through the Structural Funds*

Objective 1	Regions lagging behind in development (GDP per capita is 75% of the EU average or less)
Objective 2	Declining industrial areas
Objective 3	Long term unemployment and socio-economic integration of excluded groups
Objective 4	Unemployment associated with industrial change
Objective 5a	Structural adaptation of agriculture and fisheries
Objective 5b	Vulnerable rural areas
Objective 6	Regions with very low population density

Source: BEGG *et al.*, 1995; and EUROPEAN COMMISSION, 1997b.

extent by European ones (Fig. 1). In discussing this category, historical events should be taken into account. In fact, the 1990s change in Europe's political geography created a unique set of issues in Germany related to the different economic and social conditions of the western and eastern *Länder*. Brandenburg and Berlin are, in fact, two new *Länder* which, created after German unification, are peripheral regions within the new national context.[10] Nonetheless, this situation has impacted differently on the composition of electronics R&D in the two regions. Despite the severe problems of structural adjustment in Brandenburg, AMIN *et al.*, 1994, suggest that regional incentives and new institutions have been relatively successful in attracting inward FDI in the region. As far as the electronics industry is concerned, Fig. 5 confirms this view showing an increase in European research in Brandenburg between the first and third sub-period. In this context, ABB's 1992 investments at Cottbus (a manufacturer of electrical equipment) are of major interest. The large subsidies received by ABB were part of an attempt to establish a West German model of development. As far as Berlin is concerned, after the 1990s historical change a process of economic restructuring has taken place involving the modernization of traditional sectors. This, together with the launch of a future-oriented profile policy, seems to have attracted more German (than European) companies looking for new opportunities. In fact, Berlin has experienced an inverse trend by comparison with neighbouring Brandenburg, as shown by the almost complete recovery of domestic presence from the second to the third sub-period and by the parallel decline of European R&D in the region (Figs. 4 and 5). Therefore, in the conquest of the new eastern markets, German and European companies seem to compete with each other by locating their activity in different (although spatially close) regions – Berlin and Brandenburg, respectively.

The UK standard regions

Fig. 2 plots the two-way ANOVA results for the UK standard regions, which are grouped into five broad categories:

- regions greatly attracting European and domestic R&D: the *South East* – category 1
- regions accounting for a considerable part of European R&D in the country and for a more limited (although still significant) portion of domestic patenting: *East Anglia* – category 2
- regions showing a greater concentration of domestic (relative to European) R&D: *East Midlands, South West, West Midlands* and *North West* – category 3
- regions hosting limited domestic R&D and insignificant portions of European patents: *Wales* and *Scotland* – Category 4
- all other regions, which do not show any or any significant foreign research in R&D relative to all others – category 5.[11]

Category 1 comprising the South East of England hosts the bulk of European and UK R&D in the country (Fig. 2). This is also confirmed in the dynamic picture provided in Fig. 7, where the South East records the highest share of European and domestic ICT patents over time within the UK.

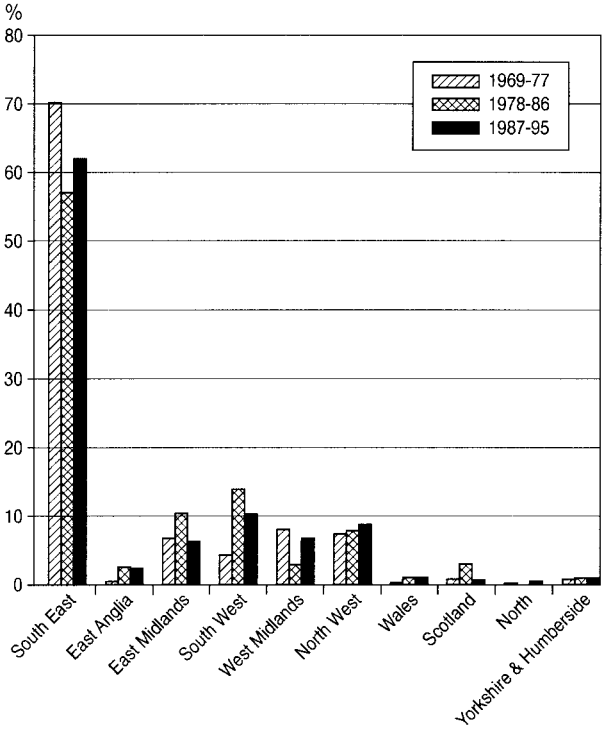

Fig. 7. *Share of research activity carried out in ICT fields by UK electronics firms located in UK regions, relative to the national domestic total, by period*

The fluctuations shown in Fig. 7 reflect, in fact, the national trend in the sub-periods considered confirming HEIM's, 1996, claims concerning decline of the UK industrial regions, due to a lack of frontier growth of spatial, technological and social factors. Nonetheless, the concentration of foreign and domestic R&D together with the fact that European electronics corporations aim to carry out research activity in all ICT sectors (Table 5) seems to suggest that the region is a *regional core* within the national context. Because the South East is the UK's most prosperous region historically (LINDERS, 1985), from the perspective of European corporations the choice of this location is likely to reflect more than the presence of sectorally-specific expertise. Rather, it seems to be more linked to local dynamic capabilities reinforced over time, as indicated by CANTWELL and IAMMARINO, 2000. In fact, if in the first instance, the dynamic socio-economic local environment established the region's competitive advantage in attracting corporate technological development, agglomeration economies were further generated reproducing and amplifying the regional *higher* order position within the international geographical hierarchy. This is all the more true for the development of core technologies (such as ICT). Due to the context-dependency of these technologies, regional cores (such as the South East) catalyse R&D investments which, in turn, emphasize and amplify local agglomeration processes as shown by the rapid growth of European companies in the last sub-period under analysis in the region under consideration.

Category 2 concerns East Anglia, hosting the highest number (after the South East) of European ICT patents and a limited presence of patents (Fig. 2). This pattern is confirmed in the dynamic picture emerging from Figs. 7 and 8. Although the magnitude of the European presence in the region fluctuates over time in line with the more general national trend, the region accounts for a great portion of the European presence in the country. Conversely, the location of domestic R&D activity in ICT sectors has been growing over time against the overall fluctuations affecting all other domestic regions. This may suggest an enhanced significance of East Anglia in the location decisions of domestic multinationals. Moreover, like the South East, East Anglia attracts European research in all ICT sectors (Table 5), thus revealing a broad spectrum of indigenous expertise. In this context, the limited (although growing) presence of domestic R&D in ICT sectors (Fig. 7) may be explained in terms of proximity to the South East, where European and domestic companies historically concentrated their activity. However, the dynamic environment of the region, reflected in the strong foreign presence as well as in the growing location of domestic R&D laboratories, might suggest a rise of the region as one of the most dynamic centres of the country, where agglomeration economies have started to work.

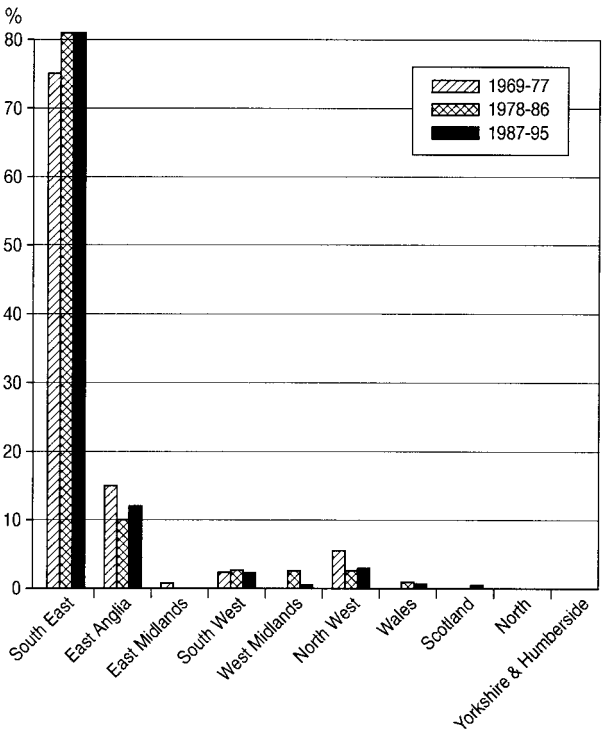

Fig. 8. *Share of research activity carried out in ICT fields by European foreign electronics firms located in UK regions, relative to the national European total, by period*

Conversely, the South West, West Midlands, East Midlands and North West (*Category 3*) provide clear examples of *lower* order regions. In all cases, the bulk of the research in ICT sectors appears to be developed mainly by indigenous firms (Fig. 2), patterns which are confirmed over time to different extents (Figs. 7 and 8). Similarly, in all four regions UK companies develop technology in specific ICT sectors (Table 5), where European companies are scarcely active. Nonetheless, local sectoral expertise does not seem to be a definitive factor driving corporate location strategy. The definition of the South West, West Midlands, East Midlands and North West as *lower* order regions is also confirmed by their overall regional economic performance. Characterized by a quite uneven socio-economic situation (rural and declining industrial areas *versus* metropolitan centres), these regions host concentrations of industrial activity in specific sectors (EUROPEAN COMMUNITIES, 1993b). The South West develops around the aeronautics and defence industries as confirmed by the activity of British Aerospace in the region. East Midlands is centred on manufacturing engineering, relating to textiles mainly as a result of historical expertise in the sector. The West Midlands' economy focuses on motor vehicle and related component manufacture driven by Rover Group, Peugeot Talbot and Jaguar. On the other hand, the North West economy is oriented towards the defence industry and (more recently) motor vehicles.

Category 4 refers to Wales and Scotland, which host

mainly (although to a small extent) domestic research and a negligible portion of European patenting (Fig. 2). In both regions, these patterns are the results of national and regional policies targeting regional development in strategic high technology sectors in order to offset vicious circles reinforcing the peripheral character of the two regions. In the literature (AMIN and TOMANEY, 1995), emphasis has been placed on regional promotional policies in Scotland. The high levels of educational attainment in the region and the co-ordinated strategic approach pursued by local institutions (e.g. Scottish Enterprise and the Scottish Development Agency – SDA) towards inward investments are the elements which attempt to upgrade both local capabilities in particular industrial clusters and consequent quality of foreign investments have been based upon. However, the dynamic framework set in Figs. 7 and 8 shows no or insignificant European research involvement in the region over time and a decline of domestic presence. As far as Wales is concerned, according to COOKE, 1980, Wales is a state-dependent economy when considering the virtually exclusive state-ownership of the traditional sectors and the declining industrial structure of the region, mainly built around the extractive industries and agriculture. Nonetheless, since the establishment of the Welsh Development Agency (WDA) in the late 1970s, regional policy has attempted to promote a local ICT industry as illustrated by the slight increase in the number of both European and UK ICT patents over time (Figs. 7 and 8). However, despite claims concerning the emergence of an innovative regional cluster in recent years (COOKE, 1998), Wales still qualified for the Structural Funds' intervention under Objective 2 in the mid-1990s (EUROPEAN COMMUNITIES, 1997a). In the context of the industry under analysis, the precarious situation of the region is confirmed in Figs 7 and 8 by the limited involvement of European and UK companies in the local development of ICT over time.

The Italian regioni

Fig. 3 summarizes the results of the two-way ANOVA for the Italian *regioni*. On the basis of the ANOVA findings, the Italian *regioni* are classified in the following broad categories:

- regions greatly attracting European R&D and hosting a substantial portion of electronics corporate domestic patenting: *Lombardia* – category 1
- regions attracting a great portion of domestic patenting activity and an important segment of European R&D: *Piemonte* – category 2
- regions accounting for a considerable portion of European R&D: *Lazio* – category 3
- regions showing a limited presence of European and domestic R&D (with a slight prominence of the latter): *Friuli-Venezia Giulia, Emilia-Romagna, Toscana* and *Liguria* – category 4
- regions hosting a limited number (with some important exceptions) of European patents: *Campania, Calabria* and *Sicilia* – category 5
- all other regions, which do not show any foreign research in ICT – category 6.[12]

Category 1 comprises Lombardia, which represents a *regional core* within the Italian context. In fact, the bulk of the European R&D has been historically located in this region, which grew explosively in the sub-period 1987–95 (Fig. 10). Similarly, Lombardia has hosted substantial portions of Italian research, whose decline over time reflects the more general national trend (Fig. 9).

Given the specialization profile of the region, widely spread across a large number of sectors,[13] the strong presence of European firms may be explained in terms of agglomeration economies attracting R&D and economic activities in a broad range of ICT fields (Table 6). As argued by CANTWELL and IAMMARINO, 1998, foreign investments are driven more by embedded location factors (e.g. dynamic capabilities reflected in successful economic performance, infrastructures and proximity to users) than by traditional location factors (e.g. cheap labour). Like Baden-Württemberg and Bayern, and the South East (UK), in this region the concentration of ICT patents may be due to agglomeration economies generated by the overall regional environment and providing a dynamic context for the

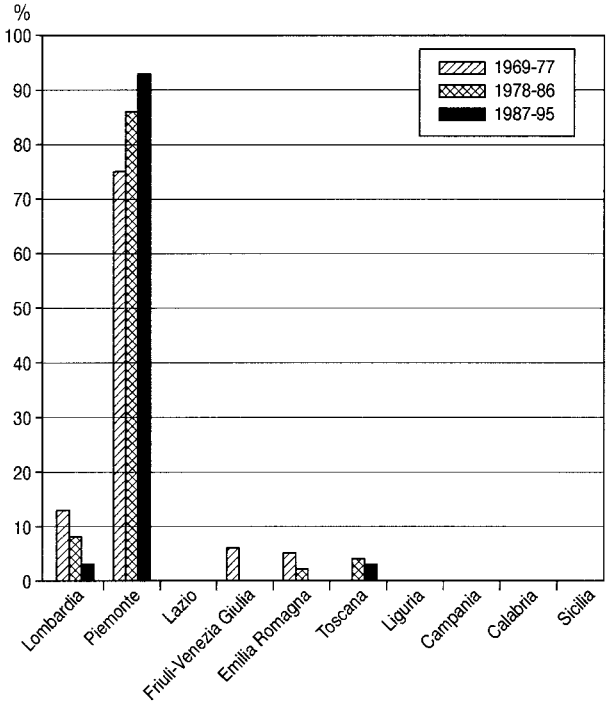

Fig. 9. Share of research activity carried out in ICT fields by Italian electronics firms located in Italian regions, relative to the national domestic total, by period

development of complex technologies (such as ICT). Therefore, ICT impacts on agglomeration by reinforcing it over time. These findings confirm Lombardia as *the* Italian regional system of innovation as claimed in other studies (e.g. CANTWELL and IAMMARINO, 1998; IAMMARINO and SANTANGELO, 2000).

Category 2 classifies Piemonte as characterized by a strong presence of domestic R&D in ICT sectors and a more limited European presence as shown in Fig. 3. In this region, where the headquarters of Olivetti are located, the percentage of Italian patents has grown over time, while the foreign presence has increased in more recent years (Figs. 9 and 10).

Both patterns reflect more general national trends. However, the slight increase in European patenting activity in the sub-period 1987–95 should be connected to the presence of the Italian multinational in the region as well as to its specialization in specific electronics fields. In fact, the portion of European R&D (although far more limited than in Lombardia) is concentrated in sectors of indigenous specialization, which are not by chance concentrated in the fields of strength of the Italian company (Table 6). This may suggest that foreign research activity is attracted by sector-specific advantages rather than by the overall local economic structure – as in the case of Lombardia – thus defining Piemonte as a *locational economy model*.

Category 3 concerns Lazio as the region hosting a considerable portion of European R&D (Fig. 3). The importance of institutional factors may explain the relatively large number of European patents. The presence of Rome as the national centre of public administration may well impact upon the location decisions of foreign companies (IAMMARINO and SANTANGELO, 2000).

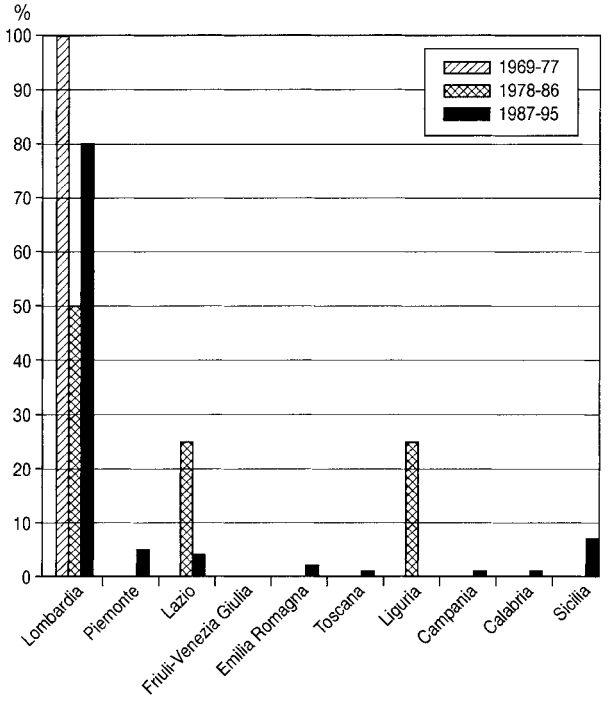

Fig. 10. *Share of research activity carried out in ICT fields by European foreign electronics firms located in Italian regions, relative to the national European total, by period*

Category 4 includes Friuli-Venezia Giulia, Emilia-Romagna, Toscana and Liguria, which show a limited presence of European and domestic corporate electronics patenting activity with a slight predominance of the latter (Fig. 3). An explanation of this pattern may be found in the fact that Italian electronics companies are mainly located in the north of the Italian peninsula. Nonetheless, it should be underlined that, although all *regioni* listed above are characterized by this common pattern, there are significant differences in their economic conditions and consequent local incentives to foreign investments (EUROPEAN COMMUNITIES, 1997b). In fact, the case of European research may be understood as mainly casual when considering the small scale of foreign innovative activity, and both the lack of sectoral overlapping with local ICT patenting in Emilia and Toscana and the total absence of patenting activity by domestic companies in Liguria (Table 6).

Category 5 refers to regions from the south grouped under Objective 1 of the EU regional policy. In all of these regions, computer technologies are the main field of research activity of European companies (Table 6). Although foreign patenting activity is rather limited and indigenous patenting is virtually absent, the presence of electronics companies in these regions may be seen in the 1990s as a result of the attempt of local regional governments to promote investment projects in industrial production including in research centres in cutting-edge technologies as a new avenue to solve the socio-economic problems of southern regions.[14] This is clearly depicted in Fig. 10, where the share of European ICT research grew suddenly from the first two to the last sub-period. Within this new approach to the 'Mezzogiorno issue', the case of the Franco-Italian joint venture involving Thomson, located in Catania (Sicilia), is illustrative. The attraction of cutting-edge research conducted by Thomson in Sicilia is the result of a policy attempt to offset vicious circles. The region has been traditionally a peripheral location within the Italian context, characterized by an agriculture-driven economy, high unemployment and slow economic growth. The attraction of a multinational research plant in the region was intended to solve short-run problems (e.g. the high youth unemployment rate) as well as to create a dynamic competitive environment in the medium/long-run. The idea is that the location of Thomson research laboratories should stimulate the generation of local expertise in developing core technologies, enlarge (and create when missing) *ad hoc* infrastructure as well as link the scientific specialization of the local university to corporate activities. In this context, it is interesting to note that Sicilia hosts the highest number of European patents by comparison with all Italian regions, except Lombardia (Fig. 10). As

illustrated in Table 5, all of these patents were granted for research into semiconductors.

As far as the Italian regional picture is concerned, two concluding remarks are needed. First, companies in the 'Third-Italy' regions in the north-east of the country confirm the absence of ICT research by both Italian and foreign companies confirm a domestic regional model of specialization in traditional sectors (IAMMARINO and SANTANGELO, 2000). Second, as argued by ANTONELLI, 1990, ICT appears to be a powerful factor for economic polarization, and increasing territorial and industrial imbalances where uneven socio-economic conditions already exist. In this sense the Italian experience is emblematic of the ICT impact on agglomeration.

CONCLUSIONS

This paper provides empirical evidence concerning the European regional development impact of ICT research activity by domestic and European foreign electronic firms. Several types of regional models of ICT technological development are identified across countries, as illustrated in Table 14: *regional cores* or systems of innovation based on agglomeration economies attracting the bulk of European R&D (i.e. Baden-Württemberg and Bayern, South East (UK) and Lombardia); rising *regional cores* (i.e. Niedersachsen and Schleswig-Holstein, and East Anglia) showing some similarities (although not fully developed yet) with the previous regions; sector-specific regional systems or *locational economies* attracting R&D in fields of local expertise (i.e. Hessen, Nordrhein-Westfalen and Reinland-Pfalz, and Piemonte); location-driven models, characterized by location specific attraction factors (such as the proximity to eastern markets for Hamburg and the centralization of Italian public administration in Rome for Lazio); *lower* order regions characterized by an almost complete lack of foreign patenting activity (North West, East Midlands, West Midlands and South West); and peripheral regions (Berlin and Brandenburg, Wales and Scotland, and Campania, Calabria and Sicilia).[15]

This taxonomy of the regional development of ICT, based on the interplay between European and domestic electronics firms, confirms that electronics corporations are mainly attracted by the overall economic structure of the regional system and by the consequent opportunities for successful corporate performance that this can offer. Moreover, as shown by the dynamic analysis, the success of innovative activity appears to be increasingly more embedded over time in local centres of expertise. In fact, by tapping into local expertise, foreign companies are able to source abroad knowledge complementary to their path of technological development. If this pattern confirms that internationalization of technological development enables the firm to enhance corporate capabilities by absorbing knowledge in local centres of expertise, it also demonstrates that local infrastructures, culture and business capabilities are key factors attracting foreign corporations. This is all the more true for ICT development when accounting for its context-dependency. In fact, due to the complex character of ICT, linkages with the local environment are crucial. Therefore, intra-European corporate development of ICT technology cannot be explained by the classic argument of corporate strategies aiming at the mere reduction of production costs. Rather, value-added factors embedded in the social system determine the decisions of European electronics MNCs as far as their regional location choices are concerned. This confirms the existence of (European) spatial hierarchies in ICT research as a result of the differences in the ranking of regional units by MNCs (SANTANGELO, 2000).

In this sense, cumulative causation mechanisms seem to shed some light on the factors driving corporate concentration of R&D in ICT technologies in the European regions under analysis. As the building of local expertise is a path-dependent process, the presence (absence) of a dynamic local environment makes the region attractive for (neglected by) MNCs' investments especially in complex cutting-edge technologies (such as ICT). In turn, the presence (absence) of corporate investments in these kinds of technologies reproduces the indigenous environment by amplifying the region's local agglomeration economies (marginality). In this sense, multinationals' R&D investments in ICT

Table 14. *Regional taxonomy on the development of ICT within the European electronic industry*

Regional models	Germany	UK	Italy
Regional cores	Baden-Württemberg and Bayern	South East	Lombardia
Rising regional cores	Niedersachen and Schleswig-Holstein	East Anglia	
Models of locational economies	Hessen, Nordrhein-Westfalen and Reinland Falz		Piemonte
Location-driven models	Hamburg		Lazio
Lower order regions		South West, East Midlands, West Midlands and North West	
Peripheral regions	Berlin and Brandenburg	Wales and Scotland	Campania, Calabria and Sicilia

strongly widen the gap between core and peripheral regions as a result of *vicious* and *virtuous* cycles. This implies that the competition for attracting foreign R&D is highly uneven as established regional systems are more likely to host cutting-edge innovative activity (COX, 1995). Nonetheless, the process is not irreversible: regions unable to adapt their institutions to cope with new opportunities may pass into relative decline and lagging regions may successfully open up to compensate with opportunities for development (METCALFE, 1996). The latter may reflect the current situation of Sicilia attempting to offset the *vicious* circle by hosting an MNC's research laboratory developing cutting-edge technology, the aim being to create a dynamic local environment by generating competitive local expertise in order to boost overall regional development.

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NOTES

1. The two authors reject the notion of *technoglobalism* (as displacing national systems of innovation) preferring the notion of technological globalization (as emphasizing the increasing significance of country-specificities) (*ibid.*).
2. *Regional cores* may be identified with local geographical units attracting corporate operations in a wider sectoral range of activities. Conversely, the narrow specialization profile of local units attracting sector-specific activities defines *models of locational economies*.
3. It is worth noting that, in the Reading database, the technological classification of each patent is rather distinct from the industrial output classification of the firm to which the patent is granted. While the primary field of technological activity of each patent derives from the US patent class system, each corporate group is allocated to an industry on the basis of its output.
4. These territorial units of analysis have also been adopted by CANTWELL and IAMMARINO, 1998, 2000, in the case of Italy and the UK respectively, and by CANTWELL and NOONAN, 2001, in the case of Germany.
5. The three-way ANOVA models run count only one observation per cell, thus preventing a between subjects analysis.
6. In the Italian case, the two-way ANOVA was run by including, first, the REGION and FIRM factors and, then, REGION and ICT. Statistically results were obtained in the former case only as reported.
7. This category will not be discussed any further in what follows.
8. In passing it should be noted that in both *Länder*, German and European electronics corporations are active, to different extents, in all ICT technological sectors (see Table 3), thus suggesting a broad spectrum of indigenous expertise that can be exploited by foreign companies.
9. Italy, which is a far less targeted location by European electronic companies across all ICT sectors, attracts some European R&D in telecommunications and office equipment and data processing systems, most probably due to the technological competencies of Olivetti in the sectors in question. In contrast, the UK shows more distributed foreign research activity across all ICT sectors appearing to be a more appealing location than the other two countries in other electrical communications systems, special radio systems and semiconductors. Historically, these sectors have been crucial in the specialization of UK electrical companies, which have developed their technological expertise around defence electronics.
10. While Brandenburg is a completely new *Land*, Berlin was formed from the reunification of West and East Berlin.
11. This category will not be discussed any further in what follows.
12. This category will not be discussed any further in what follows.
13. IAMMARINO and SANTANGELO, 2000, among others, acknowledge a broad specialization profile of Lombardia by comparison to the other Italian regions.
14. The 1990s transfer of the right to implement economic policies to local regional government was the outcome of a new approach to the 'Mezzogiorno issue' aimed at tackling the problem of the southern underdevelopment with the adoption of decentralized measures of economic policy.
15. Friuli-Venezia Giulia, Emilia-Romagna, Toscana and Liguria are excluded from this taxonomy as, in these regions, patenting activity appears to be casual as discussed above.

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