United Nations University
WIDER
World Institute for Development Economics Research

Discussion Paper No. 2001/6

ICT Clusters in Europe

The Great Central Banana and the Small Nordic Potato

Heli Koski, Petri Rouvinen and Pekka Ylä-Anttila*

May 2001

Abstract
We analyse the clustering of European ICT activities. Our focus is primarily on the ICT manufacturing industries in the EU countries. We find a clear and intensifying concentration tendency of ICT-related production and R&D. As a rule, originally specialized countries have become more so. In terms of export specialization, however, countries have become more similar. This may be a consequence of new production modes and distribution systems in the sector. Mapping of ICT businesses by postal code reveals two blocs of European ICT activity. The larger central bloc begins in the greater London area and proceeds via Randstad through Germany's industrial heartland and ends in northern Italy. The smaller Scandinavian bloc covers the Helsinki and Stockholm metropolitan areas. Our empirical investigation shows a notable country-level specialization in ICT, but businesses within the EU are concentrated into the spatial clusters that do not respect national borders.

Keywords: information and communication technology, ICT, centrifugal, centripetal, convergence, divergence, clustering, concentration, production, technology, trade, European Union, EU, new economy, weightless economy

JEL classification: D21, L16, L23, L63, O14, O52, R30

* All authors affiliated with ETLA, The Research Institute of the Finnish Economy

This study has been prepared within the UNU/WIDER project on Production, Employment and Income Distribution in the Global Digital Economy, which is directed by Professor Matti Pohjola.

UNU/WIDER gratefully acknowledges the financial contribution to the project by the Ministry for Foreign Affairs of Finland.

Acknowledgements

We would like to thank Matti Pohjola, Jed Kolko, and the participants of the UNU/WIDER meeting on ‘The New Economy in a Global Perspective’ (12-13 January 2001) for comments and suggestions.

1 Introduction

Information and communication technology (ICT) is arguably the most powerful agent for change in advanced societies. The demand-side, i.e., the use of ICT, is perhaps the more important one in considering productivity and other macroeconomic effects. Particularly interesting question is the contribution of ICT use to economic growth (see, e.g., Jalava and Pohjola, 2001). The supply-side, i.e., the production and provision of ICT-related goods and services has, however, grown to a sizeable business in its own right not only in the United States but also in Europe and elsewhere.

Both the production and use of ICT are unevenly distributed across countries and regions. While this is typical of emerging and fast evolving technologies, there are particularly significant spatial differences in the patterns of ICT production. Traditional explanations for these differences include distinct factor endowments, technologies, and policies.

Regions with originally similar or identical characteristics may develop in very different directions. Hence, the locational patterns of ICT cannot be explained in terms of factor endowments and policy regimes only. The views of new economic geography and micro-(firm-)oriented industrial economics are needed.

The tendency of particularly knowledge-driven industries to cluster geographically as well as the implications of the new growth theories have also been recognized in policy making. Countries and regions are moving their policies towards 'creating favourable framework conditions' (see, e.g., OECD 1999a). The rationale of these policies is to enhance the creation of pools of advanced factors of production that attract knowledge-intensive firms and hence lead to fast growing industrial clusters.

In this paper we look at the clustering of ICT sector in the European Union (EU). Due to data limitations, our focus is primarily in the country-level production of ICT manufactures. We address the following issues:

- Location of European ICT sector activities,
- Relative specialization of European economies in production, technology, and trade,
- Changes in ICT-orientation over time, and
- Explanations of changing patterns of ICT specialization.

2 Specialization of countries and regions

Economic literature suggests that industrial countries have become increasingly specialized in their patterns of production (see, e.g., Hummels *et al.* 1998). But why do countries and regions specialize in certain types of production? Traditional trade theory explanation relies on differing comparative advantages. This explanation has, however, proved insufficient in explaining patterns of specialization.

The more recent literature of economic geography discusses various *centripetal* and *centrifugal* forces, i.e., forces fostering spatial agglomeration and dispersion, respectively, that may prominently affect geographical specialization patterns of production. These include increasing returns to scale, which encourage firms to locate their production units to fewer places, and imperfect competition (Ottaviano and Puga 1998). Competition—unlike increasing returns to scale—is a centrifugal force, inducing firms to locate far apart to avoid local competition in the product market strengthened by geographical proximity.[1]

In addition, transportation and trade costs (e.g., tariffs, linguistic and cultural barriers) play a notable role in determining the degree of spatial agglomeration. During the past decades, the industrial world has witnessed reductions in trade barriers as well as notable improvements in communications and transportation networks. These developments have resulted in the growth of world trade and allowed for a greater country-wise specialization of production.

The emergence of the new Internet-based economy would seem to suggest, that particularly the location of production in sectors of intangible outputs, e.g., software and financial services, might witness notable changes as transportation costs decline (Quah 2000). Kolko's (2001) study concerning the spatial dynamics of the US Internet industries provides empirical evidence to support this view.

Despite of the fact that the cost of transmitting information has declined tremendously and has become largely invariant of distance, the importance of location to innovation and production remains. The primary reasons for this are the benefits that the proximity of others generates to the firms in the area, i.e., Marshallian externalities.[2] Firms located in the area of a specialized cluster of firms may benefit from knowledge spillovers; information concerning new applications or other innovative practices may spread faster among the firms that are located geographically closer to each other.[3] In addition, there are other factors fostering spatial agglomeration such as the availability of skilled labour, good infrastructure, and supporting institutions, e.g., specialized suppliers, universities, and research centres.[4] In other words, there is a difference between knowledge and information. The costs of transmitting knowledge, particularly highly contextual and uncertain knowledge that is best transmitted via face-to-face interaction, still rise with distance (Feldman and Audretsch 1999).

Knowledge spillovers and other advantages from spatial agglomeration may further create a spatial self-reinforcing mechanism fostering the growth of a regional cluster once it is established (see, e.g., Arthur 1989; David 1985). Consequently, historical events may result in a spatial lock-in effect and determine the geographical location of industrial clusters. This means that, for instance, regional or technology policy decisions

---

1 Closely related issue is the impact of IT on the dynamics of firm and industrial structure (see, e.g., Simons 2001).

2 Marshallian externalities are divided into *localization economies*, benefits that proximity of *firms producing similar goods*, and *urbanization economies*, benefits from the *overall activity* in the area (see, e.g., Belleflamme *et al.* 2000).

3 Quah's (2000) theoretical model shows that clustering emerges, due to technology spillovers across time, even when transportation costs are zero.

4 Krugman and Venables (1996), for example, formally analyze the influence of agglomeration (and economic integration) on specialization and firm location. Theoretical studies dominate the literature, but empirical explorations are increasing in number. Davis and Weinstein (1999), for example, investigate the determinants of the structure of production within regions in Japan.

and even 'accidents' may have a long-term influence on the industrial clustering dynamics.

In what follows, we view the European ICT sector and compare it to its Japanese and US counterparts in order to determine the basic similarities and differences across countries and regions. We then move on to analyse the patterns of specialization; our main focus in on the dynamics, i.e., we determine whether the tendency of the ICT sector to cluster geographically has changed in the 1990s.

Empirical studies of specialization have largely relied on the analysis of export statistics. This is indeed appropriate, if we accept the common assumption that the export of a product signals the country's comparative advantage as suggested by basic Ricardian trade theory. It is also assumed that the product is manufactured and developed in the country it is exported from. Furthermore, Ricardian trade theory has does not explain intra-industry trade. In order to address these problems we analyse, in addition to trade (exports), also production (value added) and technology (R&D).

3 ICT clusters in Europe

3.1 ICT sectors in the Triad countries

While the European ICT sector (OECD definition, see Appendix C) cannot match the comparable growth rates of its US counterpart, the trend has clearly been upwards in the 1990s. In 1997 it accounted for nearly 4 per cent of the EU business sector employment, over 6 per cent of value added, and nearly one-fourth of R&D (Table 1).

In terms of ICT *employment*, the EU and the United States are quite similar; Japan is over fifty per cent smaller than either of the two. The United States nevertheless accounts for over half of the Triad's ICT sector *value added*. The imbalance increases further if *R&D* is considered: the United States conducts well over half of the Triad's ICT sector R&D and even Japan nearly one-fourth. In terms of *R&D-intensity* and the share of ICT in total *patents* Japan seems to be the most ICT-focused of the Triad.

These imbalances are in part explained by the relative emphasis in ICT manufacturing versus services: in the EU, one-third of the employment is in manufacturing whereas in Japan the corresponding figure is nearly 60 per cent (Appendix A). Unsurprisingly the United States is the largest market for ICT-related goods and services (Appendix A).

The structural differences are also reflected in *trade patterns* (Table 2). Both the EU and the United States are net importers while Japan is a net exporter of ICT. In fact only three EU countries, Finland, Ireland, and Sweden, had a positive ICT trade balance in 1998.

Table 1
ICT employment, value added, and innovative activity, 1997

	ICT employment		ICT value added		R&D in ICT		ICT innovation	
	Persons	Of total business	PPP US$	Of total business	PPP US$	Of total business	R&D per value added	Share of patents*
	(1,000)	(%)	(mill.)	(%)	(mill.)	(%)	(%)	(%)
Austria	165	4.9	9,379	6.8	–	–	–	5.8
Belgium	130	4.3	10,029	5.8	612	20.1	6.1	9.3
Denmark	96	5.1	–	–	329	21.1	–	3.1
Finland	88	5.6	6,139	8.3	962	51.o	15.7	29.0
France	681	4.0	46,033	5.3	4,366	26.4	9.5	13.3
Germany	974	3.1	89,154	6.1	5,653	20.1	6.3	6.7
Greece	–	–	–	–	76	46.9	–	24.4
Ireland	56	4.6	–	–	378	47.7	–	7.4
Italy	671	3.5	53,837	5.8	1,677	26.5	3.1	16.6
Netherlands	199	3.8	14,131	5.1	791	19.6	5.6	5.1
Portugal	94	2.7	6,155	5.6	50	23.5	0.8	6.6
Spain	–	–	–	–	551	21.4	–	16.8
Sweden	174	6.3	11,773	9.3	1,427	27.9	12.1	5.7
UK	1,112	4.8	81,919	8.4	3,227	21.8	3.9	15.9
EU	**4,441**	**3.9**	**328,549**	**6.4**	**20,098**	**23.6**	**6.1**	**11.0**
Japan	2,060	3.4	151,909	5.8	26,127	40.4	17.2	21.0
USA	4,521	3.9	581,540	8.7	59,916	38.0	10.3	18.4

Note: * Share of ICT patents refers to the ratio of ICT-related to total patents granted to the country by the United States Patent Office.

Source: OECD (2000a) and (2000c).

Finland, Ireland, and Sweden are drawn apart from the rest of the union members in other respects as well (Table 1): ICT accounts for the largest share of business sector *employment* in Sweden (followed by Finland and Denmark), ICT accounts for the largest share of business sector *value added* also in Sweden (followed by the United Kingdom and Finland), and ICT-related activities account for the largest share of business sector *R&D* in Finland (followed by Ireland and Sweden).

The last column of Table 2 shows the ratio of ICT trade balance to overall trade, i.e., to the average of exports and imports. According to this measure, Japan and Finland are relatively the biggest net exporters of ICT among the Triad countries while Greece and Portugal are relatively the biggest net importers of ICT.

In the most detailed available trade statistics,[5] ICT manufactures include nearly 200 goods, but the top ten accounted for 60 per cent of OECD trade in 1998. The six most traded goods are various electronics and computer parts and components. Colour

5 OECD *International Trade by Commodities Statistics*, Harmonized System 6-digit or finest available level.

televisions and three classes of communications equipment also make the top ten. With the exception of mobile communication devices, Japan is a net exporter of the top ten products. The United States is a net importer of computer-related parts and accessories as well as televisions, but a net exporter of integrated circuits, central processing units, and communications equipment. See Appendix A for further details.

Table 2
Trade of ICT goods and services, 1998

	ICT exports		ICT imports		ICT trade balance	
	US$ (bn)	% of total exports	US$ (bn)	% of total exports	Exports-imports (bn)	Ex.-Im.per (ex.+im.)/2
Austria	4.8	5.0	7.9	8.2	-3.1	-49.3
Belgium/Lux.	12.8	6.7	13.3	7.4	-0.6	-4.4
Denmark	3.9	8.3	5.4	12.7	-1.5	-32.8
Finland	9.8	19.6	6.2	16.1	3.6	44.9
France	35.4	9.4	37.8	11.1	-2.4	-6.5
Germany	53.6	8.6	64.2	11.0	-10.6	-18.0
Greece	0.3	4.2	2.2	8.6	-1.8	-146.8
Ireland	19.4	32.6	13.6	33.9	5.8	35.3
Italy	13.7	4.4	23.4	8.5	-9.6	-51.9
Netherlands	34.8	14.6	36.2	16.7	-1.4	-4.1
Portugal	2.1	6.3	3.7	8.4	-1.6	-53.8
Spain	8.4	5.3	13.5	8.6	-5.1	-46.4
Sweden	15.5	14.9	12.7	14.2	2.8	20.0
UK	55.8	15.0	57.5	14.9	-1.7	-2.9
EU *	**270.4**	**10.1**	**297.6**	**11.8**	**-27.2**	**-9.6**
Japan	101.4	24.0	47.0	13.5	54.3	73.2
USA	147.1	15.2	182.9	16.4	-35.9	-21.7

Note: * Includes intra-EU trade.
Source: OECD (2000a).

3.2 Specialization in ICT manufacturing

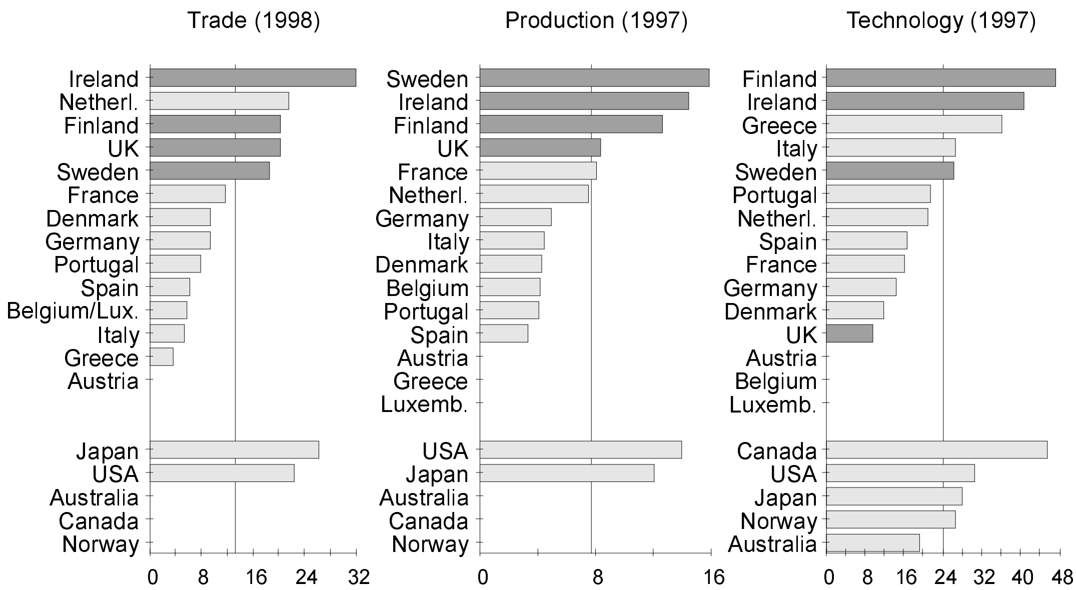
Above we considered both ICT manufacturing and services in the Triad countries. Below we use ICT manufacturing data due to the rather patchy time-series on ICT services. Besides the Triad, we include Australia, Canada, and Norway whenever we have sufficient data. In case of production and R&D, we are forced to use a narrower definition of ICT (see Appendix C).

3.2.1 Current ICT specialization

Figure 1 illustrates ICT trade, production, and technology specialization, as measured by, respectively, the relative share of ICT in the total manufacturing exports, value added, and R&D. Only Finland, Ireland, and Sweden are consistently specialized, i.e., above the EU average, according to all three measures. The United Kingdom ranks fourth among the EU countries in trade and production specialization, but last in technology specialization.

The ‘high ICT manufacturing intensity’ countries in the EU—Finland, Ireland, Sweden, and (possibly) the United Kingdom—have chosen somewhat different strategies in developing their ICT sectors. Ireland and the United Kingdom have attracted business activities of foreign firms, whereas in Finland and Sweden, value added is mostly created by domestic companies (Appendix A). The composition of ICT is also different across the four countries: Ireland and the United Kingdom are most active in information technology whereas Finland and Sweden are active in communication technology (Appendix A).

Figure 1
ICT trade, production and technology specialization
(the share of ICT in total manufacturing exports, value added, and R&D)



Note: Missing horizontal bar indicates, that data concerning the country in question was not used in the dynamic analysis. The vertical gridline indicates the unweighted average of the available EU countries.

Source: OECD (2001); Eurostat Datashop at Statistics Finland (2000), OECD (2000b).

In addition to the cross-section specialization patterns of countries, it is of great interest to explore whether, and in which ways, the specialization patterns have changed over time. The dynamic movements in the distribution of given parameters can be empirically investigated by using convergence measures.

3.2.2 Measuring changes in ICT specialization

We use a simple measure of *σ-convergence* (see Friedman 1992), the coefficient of variation, to capture inter-temporal changes in the distribution of the variables describing the ICT specialization. Shrinking variance over time indicates that the sampled group is converging in terms of the characteristic in question (Boyle and

McCarthy 1997).[6] Thus, in the cross-country setting, σ-convergence means that originally poorly performing countries are *catching up* with originally well performing countries. In other words, σ-convergence shows whether the countries are converging or diverging with respect to their ICT specialization during the sample period.

We also investigate changes in the ordinal ICT specialization rankings by employing two ranks (see also Koski and Majumdar 2000): the *Wilcoxon Matched-Pairs Signed Rank Test* (see, e.g., McClave and Benson 1994) and *Kendall's W* (see, e.g., Kendall and Gibbons 1990). The Wilcoxon test measures whether the ordinal rankings of countries have notably changed between each year and the base year of the study, whereas Kendall's W measures the intra-distributional mobility over the whole period. The Wilcoxon and Kendall tests capture the phenomenon of *leapfrogging*, or *β-convergence* (see Appendix B for the test statistics).

As Koski and Majumdar (2000) show, the absence of σ-convergence does *not* necessarily mean that catching up has not taken place. The variance of the distribution may not decrease even if catching up takes place, when initially less specialized countries increase specialization so drastically that they leapfrog the initially more specialized countries. Thus, both β-convergence and σ-convergence must be examined.

We explore distributional changes in ICT trade, production, and technology specialization as discussed above. The coefficient of variation is used to measure the presence of σ-convergence, and the Kendall's W and the Wilcoxon Matched-Pairs Signed Rank Test is used to measure β-convergence, i.e., intra-distributional changes in the rank orders.

3.2.3 Changes in ICT specialization

The importance of ICT relative to other manufacturing branches has increased in the 1990s. The proportion of valued added of the ICT sector to that of manufacturing as a whole has grown from 7.25 per cent to 8.5 per cent during the period of 1991–97.

In terms of *value added*, Japan and the United States have been among the most ICT-specialized industrial countries, but some European countries have reached, and even leapfrogged, them during the 1990s. Ireland has been among the top three countries since 1994, and Sweden appeared to be the most specialized country in 1997. The country that has most prominently risen within the rank order is Finland. In 1991, Finland was the least specialized country in the sample, whereas in 1997 it had risen to the fourth place. Regardless of these few exceptions, the sampled countries have not dramatically moved within the rank order. Some leapfrogging has occurred but our data suggest that the phenomenon has not been statistically significant. The pair-wise comparisons of the Wilcoxon Matched-Pairs Singed Ranks Test and Kendall's W that suggest that the sampled countries have not significantly β-converged.

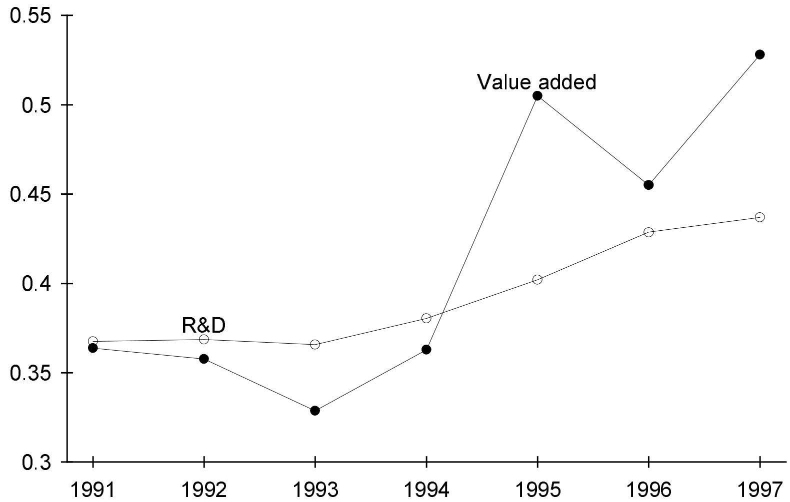
The coefficients of variation for the value-added share has increased during the sampled period of time (see Figure 2). This indicates that the countries have been diverging from

---

6 We may note here that our definition of convergence is the one used in the growth literature. Kolko, (2001), for example, uses the definition of convergence of the economics of geography.

one another in their ICT specialization. In other words, previously more ICT-orientated countries have further increased their 'distance' to the less specialized countries.

Figure 2
Coefficients of variation for the R&D and value-added shares of ICT manufacturing



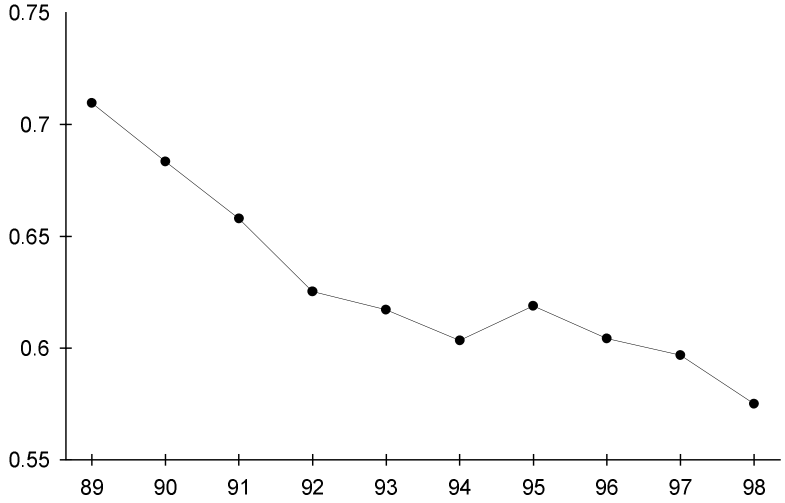
Unlike value added, the share of ICT-related *R&D* in the manufacturing total has decreased. In 1991, ICT-related R&D was approximately 5 per cent of the total manufacturing, whereas the corresponding figure in 1997 was about 4 per cent.

Figure 2 illustrates that the coefficient of variation of technology specialization has clearly been increasing since 1988. This means that the sample countries have become increasingly diverged in their technology specialization. The values of Kendall's W and the Wilcoxon test suggest that the ranking have not changed significantly. Canada has been relatively the biggest investor in ICT-specific R&D all years except in 1997 when Finland, which was eleventh in 1991, became the top country. Thus, the countries more specialized in ICT-related R&D in the early 1990s have further drifted away from the initially less specialized countries. Note, however, that there are few exceptions, e.g., Finland. In other words, there is a clear pattern of increasing ICT technology specialization.

The growth of ICT production is reflected in trade patterns. In 1989, ICT accounted for 11 per cent of manufacturing exports; in 1998 the corresponding figure was almost 15 per cent among the sample countries. Without Ireland –which has been the most ICT export orientated country in the sample since 1995—the non-European countries would dominate the picture. Japan and the United States have been among the three most ICT export-specialized countries, respectively, from 1989 to 1998.

Figure 3 shows that the coefficient of variation of ICT trade specialization has, unlike in the cases of production and technology, decreased from 1989 to 1998. Thus, initially less specialized countries have been catching up. The Kendall's W and the Wilcoxon tests suggest, however, that no leapfrogging has taken place.

Figure 3
Coefficient of variation for the export share of ICT goods



In summary, our data suggest that the sample countries have diverged from each other in ICT production and technology specialization, but converged in ICT trade specialization. This means that even though the production and innovation of ICT manufacturing is increasingly concentrated in certain countries, trade of ICT products is more evenly distributed. It seems plausible that this has happened due to substantial production and distribution networking of the ICT sector. In other words, this may be a consequence of ICT firms buying relatively large shares of their intermediate inputs from abroad and further processing them into the final export products. Also increasing 'transit' transportation of ICT products—due to trade liberalization and changing business logistics—may have substantially influenced the inter-temporal changes in ICT trade specialization patterns.

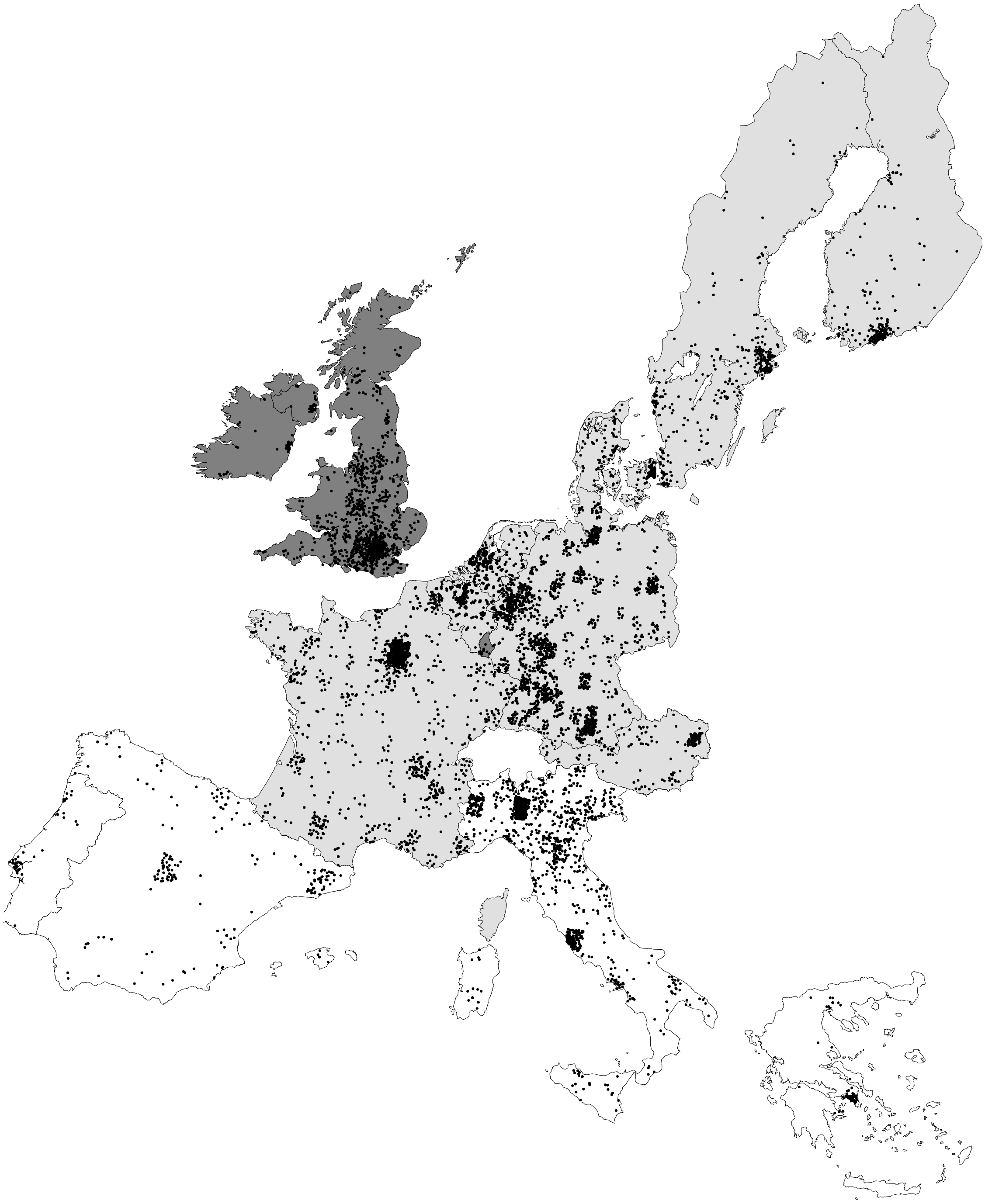
3.3 Regional ICT specialization

Above we have established which EU countries seem to be specialized in ICT and how specialization patterns have changed over time. Due to data limitations, we are unable to conduct a similar analysis at the regional level. We use a mapping technique in order to get some idea of the clustering of the ICT sector within EU countries (Figure 4).

Figure 4 illustrates the locations of ICT-related firms in the EU area. A dot represents one business establishment and the grey areas indicate the relative share of ICT firms at the country level.

From Figure 4 it is immediately obvious that ICT sector activities seem to be concentrated in urban centres. While this is indeed quite intuitive, this tendency does depend on the type of business in question. Hazley (2000), for example, uses a similar technique in studying forest-related businesses in the EU area and did not find a similar pattern.

Figure 4
Locations of ICT-related business establishments with the EU



Note: The map shows a dot for each business establishment found at the source under the categories *Information Technology* and *Telecommunications Industry,* a total of over 11,000 establishments. Dots are randomly distributed within the postal code in question. Distributors and retailers excluded. Information is self-reported by the firms. A firm may comprise of several establishments. Dark grey highlight indicates, that over 4% of the non-distributors / non-retailers in the country are ICT firms. Light grey (white) indicates countries where the corresponding figure is 2.5–4% (below 2.5%).

It seems that there are two blocs of European ICT activity. The larger central European bloc–the 'great central banana'–begins in the greater London area and proceeds via Randstad (Netherlands) through Germany's industrial heartland and ends in northern Italy. The smaller Scandinavian bloc–the 'small Nordic potato'–covers the Helsinki and Stockholm metropolitan areas. There are, however, ICT concentrations outside these two blocs, e.g., Paris metropolitan area. Similar blocs can be recognized by analysing regional labour force statistics (Appendix A).

Source: Data extracted from *The Europages CD-Rom 2001*.

As such, the densities of ‘dots’ cannot be compared across countries, since the population density and other factors vary greatly from one country to the next. The shaded areas, which may be used for cross-country comparisons, in Figure 4 suggests, that there seems to be a north-south division in ICT-intensity.

4 Conclusions

In accordance with predictions of the new growth theory and the new economic geography, our data show that there seems to be a clear tendency of ICT related production and innovation to cluster geographically. Our empirical explorations also indicate that regional (country-level) specialization on ICT has increased in the 1990s.

Three European countries—Finland, Ireland and Sweden—are currently specialized in ICT production, technology and trade. Especially in Finland, the role of ICT has grown substantially during the past decade. In the beginning of 1990s, Finland was one of the least ICT-specialized industrial countries; now its amongst the most ICT-intensive countries in the world. As a rule, however, the rankings of the sample countries according to the three measures used have changed relatively little.

Our analysis suggests that certain countries have become relatively more specialized in ICT production and R&D than others during the 1990s, i.e., countries have diverged. In terms of export specialization, however, the countries seem to have converged, i.e., they have become more similar. Convergence in export specialization stresses the increasingly important role of production and distribution networking in the sector. The trade of ICT products, intermediate goods, and components has rapidly increased as a consequence of the new production modes and distribution systems. This suggests, that great caution should be exercised in interpreting export-specialization figures across countries. Export specialization may or may not be an indication of comparative advantage in ICT-related goods.

As our mapping exercise illustrates, ICT-related businesses in Europe are concentrated around major urban centres. The ‘great central (or blue) banana’ is a well-known concept in the literature; various studies on economic growth regions have identified this shape, covering an area from London via Randstad through industrial areas of Germany and Switzerland to northern Italy. In addition to the ‘banana’, we find a ‘small Nordic potato’ covering the metropolitan areas of Stockholm and Helsinki. The major difference between the two strong European ICT blocs is that the industrial activities in the ‘Banana’ is more focused on information technology (IT), whereas the ‘Potato’ is more focused on communication technology (CT). It seems that even though our analysis shows a notable country-level specialization in ICT, businesses within the EU are concentrated in the spatial clusters that do not respect national borders.

It is currently unclear, how the (technological) convergence of IT, CT, consumer electronics, and the content industry will change the locational patterns of European ICT. Until now, developments in the production and use of ICT have clearly been driven by technology. It seems plausible to argue that as the technology goes mainstream, successful competition in the ‘information industry’ will require solid understanding of the dynamics of the content industry, which may in turn require at least some presence of manufacturers and service providers in major centres of content provision. Currently much of professionally edited content in the Internet originates from Manhattan, San Francisco, or London. Hollywood overwhelmingly dominates the entertainment industry. New York and London are centres of music business. As far as Europe is concerned, radio, television, newspapers, and magazines are largely national, not least because of linguistic reasons. It is not implausible to argue that in the coming years, the technological convergence will further increase the spatial clustering of ICT production and innovative activity. Kolko (2001), on the other hand, suggests that centrifugal forces dominate in the high IT-intensive US industries *after* controlling for regional labour force composition and the nature of the industry. Two points are, however, noteworthy: availability of high-skilled labour is indeed one of the key reasons for a firm to locate within a cluster of similar businesses, and that the high-IT industries are *not* directly comparable to the ICT sector, not least because the latter is largely comprised of manufacturing-related activities.

One of the main messages from the policy point of view is that there seems to be a certain path dependence: countries with strong ICT sectors tend to strengthen their positions—leapfrogging is difficult. This underlines the need to avoid wish-driven policies of 'great leaps forward' to the forefront of ICT *provision*. It might be better to build on existing strengths and make the most of ICT *use*.

It is evident that being a large producer of ICT is *not* a necessary condition for being an advanced user of ICT. In light of economic history the use of new technologies is, in the long run, more important than just provision. This emphasizes the role of diffusion policies.

Our data on ICT-related businesses indicate that clustering does not necessary obey national borders. This implies that focusing on national policies is insufficient and rather underlines the importance local and/or regional policies in promoting ICT.

Appendix A: Statistical supplement

Table A1
Sectoral distribution of ICT employment and value added, 1997

	ICT employment by sector (%)			ICT value added by sector (%)		
	Manufacturing	Telecomm.	Other services	Manufacturing	Telecomm.	Other services
Austria	24	39	37	24	38	38
Belgium	18	23	60	18	34	48
Denmark	23	20	57	–	–	–
Finland	42	20	38	47	22	30
France	35	25	40	27	37	35
Germany	38	23	39	34	42	25
Greece	–	–	–	–	–	–
Ireland	62	21	17	–	–	–
Italy	28	27	46	18	55	27
Netherlands	39	21	40	29	38	34
Portugal	28	22	50	18	51	31
Spain	–	–	–	–	–	–
Sweden	34	21	45	36	25	39
UK	27	17	55	23	28	49
EU *	**33**	**23**	**44**	**27**	**37**	**36**
Japan	59	11	31	60	28	12
USA	35	27	38	30	32	39

Note: * = figures refer to the unweighted means of the available countries.

Source: OECD (2000a).

Table A2
ICT market size and number of enterprises, 1997

	Implied market size (bn PPP US$)			Numer of enterprises		
	Manufacturing	Telecomm.	Other servcies	Manufacturing	Telecomm.	Other services
Austria	10	6	15	410	133	8,774
Belgium	6	5	24	–	–	–
Denmark	4	0	–	897	127	10,864
Finland	7	3	35	688	191	4,937
France	42	25	–	1,157	743	28,967
Germany	63	39	–	1,779	–	–
Greece	–	–	–	–	–	–
Ireland	8	–	–	217	–	1,098
Italy	41	44	59	13,452	314	67,758
Netherlands	14	9	7	–	–	–
Portugal	5	5	8	509	115	6,599
Spain	17	16	–	1,642	–	–
Sweden	11	6	17	1,358	206	13,457
UK	52	41	137	7,145	4,005	84,370
EU *	**281**	**197**	**310**	**29,254**	**5,834**	**226,824**
Japan	229	81	52	17,552	6,024	20,876
USA	465	319	435	15,676	38,856	118,277

Note: * = figures refer to the sums of the available countries.

Source: OECD (2000a).

Table A3
Share of foreign affiliates of the national manufacturing value added

	Office accounting and computing machinery (30, ISIC rev. 3)	TV, radio, communications, etc. equipment (32, ISIC rev. 3)
Finland (1994)	47.0	6.1
Ireland (1996)	96.9	91.4
Sweden (1996)	20.9	3.2
UK (1995)	75.8	58.9

Note: Data available only on two-digit industries.
Source: OECD (1999b).

Table A4
Percentage shares of ICT manufacturing exports, 1998

Industry:	3000	3130	3210	3220	3230	3312	3313
Short name:	Computers, etc.	Cables and wires	Components, etc.	Telecomm	Consumer electr.	Instruments	Process control eq
Austria	17	7	**32**	11	17	**16**	1
Belgium	31	4	15	16	**27**	7	0
Denmark	23	2	8	27	23	**17**	**1**
Finland	12	3	5	**64**	10	5	**1**
France	32	4	**24**	18	11	12	0
Germany	29	4	21	17	7	**21**	0
Greece	13	**27**	2	**31**	14	13	0
Ireland	**74**	2	13	9	1	2	0
Italy	29	8	**21**	19	9	14	**1**
Netherlands	**63**	1	18	5	5	6	0
Portugal	5	**27**	17	3	**40**	8	0
Spain	27	**11**	12	15	**26**	9	0
Sweden	7	4	6	**55**	21	7	0
UK	**41**	2	15	20	9	13	0
EU mean *	**29**	**8**	**15**	**22**	**16**	**11**	**0**
Japan	34	1	34	11	12	6	1
USA	34	2	32	11	7	13	0

Note: * Unweighted means of the percentage shares of the EU countries.
Source: OECD (2001).

Table A5
Measures of σ and β convergence of ICT specialization in production, exports and R&D

	Production		Exports		R&D	
Year	σ convergence	Wilcoxon Z (compared to year 1991)	σ convergence	Wilcoxon Z (compared to year 1989)	σ convergence	Wilcoxon Z (compared to year 1991)
1989			0.170	0.000 *		
1990	0.364		0.683	0.000 *		
1991	0.358		0.658	0.000 *	0.368	
1992	0.329	-0.270 *	0.625	-0.277 *	0.369	-0.432 *
1993	0.363	-0.300 *	0.617	-0.277 *	0.366	-0.320 *
1994	0.505	-0.790 *	0.603	-0.302 *	0.380	-0.387 *
1995	0.455	-1.029 *	0.619	-0.187 *	0.402	-0.281 *
1996	0.528	-0.884 *	0.604	-0.000 *	0.429	-0.079 *
1997		-0.554 *	0.597	-0.361 *	0.437	-0.095 *
1998			0.575			

Note: * means that H_0 hypothesis cannot be rejected at the 0.01 level.

Table A6
Kendall's W for specialization in production, exports and R&D

	Period	Kendall's W	χ^2
Production	1990-97	0.858	78.069 *
Exports	1989-98	0.974	163.32 *
R&D	1991-97	0.891	99.821 *

Note: * means that H_0 hypothesis ('complete agreement' across years) cannot be rejected at the 0.01 level.

Table A7
Top twelve regions in terms of ITCE occupational intensity, 1999

Country	Region	Number of ITCE employees (thousand)	% ITCE
Sweden	Stockholm	40.6	4.9
France	Île de France	207.1	4.2
Netherlands	Utrecht	23.4	4.2
Finland	Uusimaa	28.8	4.1
Netherlands	Zuid-Holland	60.7	3.8
UK	Berkshire, Bucks, Oxfordshire	41.4	3.8
Netherlands	Noord-Holland	45.6	3.7
Belgium	Rég. Bruxelles Cap.	12.0	3.6
Belgium	Brabant Wallon	4.8	3.5
Austria	Wien	24.2	3.2
UK	Bedfordshire, Hertfordshire	25.0	3.1
UK	Inner London	35.4	3.1

Note: Regions with data too low to be reliable excluded. UK data for 1998. No data available for Ireland. ITCE consists of the following International Standard Classification of Occupations (ISCO): computer professionals (ISCO 213), computer associate professionals (ISCO 312), and optical and electronic equipment operators (ISCO 313).

Source: EMERGENCE Newletter 3/2001 (IES; Eurostat: Community Labour Force Survey).

Table A8
Top twelve regions in terms of IT sector employment intensity, 1999

Country	Region	Numbers employed in IT sectors (thousand)	% of total employment in IT sector
UK	Berkshire, Bucks, Oxfordshire	60.7	5.6
Sweden	Stockholm	30.8	3.7
UK	Bedfordshire, Hertfordshire	29.2	3.6
France	Île de France	163.9	3.4
UK	Surrey, East-West Sussex	38.2	3.3
Finland	Uusimaa	21.1	3.0
UK	Avon, Gloucestershire, Wiltshire, N. Somerset	30.7	2.9
UK	Hampshire, Isle of Wight	23.8	2.8
Netherlands	Utrecht	15.3	2.8
Spain	Communidad de Madrid	51.0	2.7
Italy	Lazio	47.5	2.6
Germany	Oberbayem	50.7	2.6

Note: Regions with data too low to be reliable excluded. UK data for 1998. No data available for Ireland. IT consists of the following branches: manufacture of office machinery and computers (NACE 30), and computer and related activities (NACE 72).

Source: EMERGENCE Newletter 3/2001 (IES; Eurostat: Community Labour Force Survey).

Table A9
OECD trade top ten ICT manufactures in 1998: net exports (exports–imports) by country (value, $1,000,000)

Product*	Computer parts and accessories	Digital integrated circuits	Computer storage units	Computer input and output units	Non-digital integrated circuits	Central processing units	Mobile communic. devices	Colour televisions	Line communic. equipment	Wireless communic. eq. parts
Austria	-430	**9**	-156	-310	-26	-252	-207	-235	-284	-85
Belgium/Lux.	-173	-270	-51	-103	-73	**59**	-376	**460**	**158**	-17
Denmark	-158	-162	-194	-284	-132	**237**	-249	-58	-115	-87
Finland	-400	-411	-248	**55**	-328	**3100**	**121**	**41**	**361**	**302**
France	-1948	**797**	-855	-857	**46**	**1755**	**843**	**10**	**239**	**118**
Germany	-3450	-1412	-2538	-2625	-498	**2387**	-436	-907	**920**	-189
Greece	-203	-34	-46	-87	-5	-307	-18	-145	-149	-54
Ireland	**1016**	**45**	-191	**363**	**50**	**156**	**734**	-82	**106**	-27
Italy	-800	-1155	-774	-940	**218**	-1663	**17**	-573	**136**	**140**
Netherlands	-2089	**722**	-206	**639**	**611**	-188	-218	-666	-286	**106**
Portugal	-221	-80	-63	-187	-47	-243	-84	-128	-218	-59
Spain	-922	-77	-321	**124**	-153	-672	-506	**361**	-237	-96
Sweden	-558	-575	-319	-546	-151	**4383**	-750	-18	**632**	**795**
UK	-3631	-723	-2559	-726	-180	**2254**	**2934**	**621**	-594	**249**
Japan	**5137**	**6050**	**2145**	**4743**	**1349**	**671**	-1732	**114**	**1190**	**1270**
USA	-7900	**1100**	-13407	-11725	**1632**	**2018**	**1571**	-4822	**651**	**1498**

Note: * Product names refer to the following HS commodity classes:

Computer parts and accessories (HS code 847330): Parts and accessories of automatic data processing machines, optical readers, and machines for transcribing data, etc. and units thereof.

Digital integrated circuits (HS code 854211): Monolithic (elements inseparably associated) integrated circuits, digital.

Computer storage units (HS code 847193): Magnetic and optical storage units (hard drives, etc.), whether or not presented with the rest of a system.

Computer input and output units (HS code 847192): Computer input and/or output units (keyboards, displays, printers etc.), whether or not presented with the rest of a system, etc.

Non-digital integrated circuits (HS code 854219): Monolithic (elements inseparably associated) integrated circuits, not elsewhere specified (not digital or hybrid), including unmounted chips, dice, and wafers as well as analogue and mixed signal units.

Central processing units (HS code 847191): Digital processing units, whether or not presented with the rest of a system, etc.

Mobile communication devices (HS code 852520): Radio- or telegraphic transmission devices incorporating reception apparatus (two-way radios, cellular phones, etc.).

Colour televisions (HS code 852810): Colour television receivers, video monitors and projectors.

Line communication equipment (HS code 851790): Parts of electrical apparatus for line telephone or line telegraphy, including cordless handsets, apparatus for carrier-current line systems or for digital line systems, videophones, etc.

Wireless communication eq. parts (HS code 852990): Parts solely or principally for radiotelephony or radio broadcasting transmission apparatus; radar, navigation or remote-control apparatus; radiotelephony or radio broadcasting reception apparatus; and television, video monitors or projectors.

Source: OECD *International Trade by Commodities Statistics,* Harmonized System CD-ROMs

Appendix B: Formulae

The Wilcoxon Matched-Pairs Signed Rank Test statistic is calculated as follows:

Test statistic: $$z = \frac{T_{+} - \frac{n(n+1)}{4}}{\sqrt{\frac{n(n+1)(2n+1)}{24}}}$$

where T_{+} = the smaller of the positive and negative rank sums. The hypothesis that the probability distributions of the rankings of the countries for the two years considered are identical—i.e. that there is no β-convergence—can be rejected if z gets such a value that $z < -z_{\alpha/2}$ or $z > z_{\alpha/2}$.

The Kendall's W test uses the following test statistic:

$$W = \frac{12S}{m^2(n^3 - n)}$$

where m is the number of rankings, n is the number of countries and S is the sum of squares of deviations of the annual rankings of the countries around their mean rankings. Kendall's W ranges from 0 to 1. It gets the value of 1 if there is no mobility within the distribution, or if there is no β-convergence, over the time period studied. The smaller the value of W, the greater the mobility within the distribution.

The Wilcoxon test, unlike the Kendall's W, also takes into account the orders of magnitudes of the differences in the ranked observations.

Appendix C: Definitions of the ICT sector

The OECD definition (http://www.oecd.org/dsti/sti/it/stats/defin.htm, ISIC rev. 3):

ICT manufacturing:

3000 Manufacture of office, accounting and computing machinery

3130 Manufacture of insulated wire and cable

3210 Manufacture of electronic valves and tubes and other electronic components

3220 Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy

3230 Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods

3312 Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment

3313 Manufacture of industrial process control equipment

Services—goods related:

5150 Wholesale of machinery, equipment and supplies

7123 Renting of office machinery and equipment (including computers)

Services—intangible:

6420 Telecommunications

7200 Computer and related activities.

Our narrower definition of ICT manufacturing:

3000 Manufacture of office, accounting and computing machinery.

3200 Manufacture of radio, television and communication equipment and electronic components.

References

Arthur, W. B. (1989). 'Competing Technologies, Increasing Returns and Lock-in by Historical Events'. *Economic Journal,* 99: 116-31.

Beardsell, M., and V. Henderson (1999). 'Spatial Evolution of the Computer Industry in the USA'. *European Economic Review,* 43: 431-56.

Belleflamme, P., P. Picard, and J.-F. Thisse (2000). 'An Economic Theory of Regional Clusters'. *Journal of Urban Economics,* 48: 158-84.

Boyle, G. E., and T. G. McCarthy (1997). 'A Simple Measure of β-Convergence'. *Oxford Bulletin of Economics and Statistics*, 59: 257-64.

David, P. (1985). 'Clio and the Economics of QWERTY'. *American Economic Review*, 75: 332-7.

Davis, D. R., and D. E. Weinstein (1999). 'Economic Geography and Regional Production Structure: An Empirical Investigation'. *European Economic Review*, 43: 379-407.

Feldman, M. P., and D. B. Audretsch (1999). 'Innovation in Cities: Science-based Diversity, Specialization and Localized Competition'. *European Economic Review*, 43: 409-29.

Friedman, M. (1992). 'Do Old Fallacies Ever Die?' *Journal of Economic Literature*, 30: 2129-32.

Hazley, C. J. (2000). *Forest-Based and Related Industries of the European Union—Industrial Districts, Clusters and Agglomerations*. Helsinki, Finland: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy.

Hummels, D., D. Rapoport, and K.-M. Yi (1998). Vertical Specialization and the Changing Nature of World Trade'. *FRBNY Economic Policy Review*, June: 79-99.

Jalava, J., and M. Pohjola (2001). 'Economic Growth in the New Economy: Evidence from Advanced Economies'. WIDER Discussion Paper 2001/5. Helsinki: UNU/WIDER.

Kendall, M., and J. D. Gibbons (1990). *Rank Correlation Methods*, Fifth Edition. London: Arnold.

Kolko, J. (2001). 'Silicon Mountains, Silicon Molehills: The Geography of Internet Industries in the US'. WIDER Discussion Paper 2001/2. Helsinki: UNU/WIDER.

Koski, H., and S. Majumdar (2000). 'Convergence in Telecommunications Infrastructure Development in OECD Countries'. *Information Economics and Policy*, 12: 111-31.

Krugman, P. (1980). 'Scale Economies, Product Differentiation and the Pattern of Trade'. *American Economic Review*, 70: 950-59.

Krugman, P., and A. J. Venables (1996). 'Integration, Specialization, and Adjustment'. *European Economic Review*, 40: 959-67.

McClave, J. T., and P. G. Benson (1994). *Statistics for Business and Economics*. Sixth Edition. San Francisco: Dellen/Macmillan.

OECD (1999a). *Boosting Innovation—The Cluster Approach*. Paris: Organization for Economic Cooperation and Development.

OECD (1999b). *Measuring Globalisation—The Role of Multinationals in OECD Economies*. Paris: Organization for Economic Cooperation and Development.

OECD (2000a). *Measuring the ICT Sector*. Paris: Organization for Economic Cooperation and Development.

OECD (2000b). *The OECD Analytical Business Enterprise R&D Database (ANBERD)*. Paris: Organization for Economic Cooperation and Development.

OECD (2000c). *Science, Technology and Industry Outlook*. Paris: Organization for Economic Cooperation and Development.

OECD (2001). *The OECD Structural Analysis Database (STAN, unofficial version)*. Paris: Organization for Economic Cooperation and Development. Forthcoming.

Ottaviano, G. I. P., and D. Puga (1998). 'Agglomeration in the Global Economy: A Survey of the "New Economic Geography" '. *World Economy*, 21: 707-31.

Quah, D. (2000). 'Internet Cluster Emergence'. *European Economic Review*, 44: 1032-44.

Quah, D. (2001). 'ICT Clusters in Development: Theory and Evidence'. Mimeo.

Simons, K. (2001). 'Information Technology and the Dynamics of Firm and Industrial Structure: The British IT Consulting Industry as a Contemporary Specimen'. Paper presented at the UNU/WIDER meeting on The New Economy in a Global Perspective, 12-13 January. Helsinki: UNU/WIDER.

UNU World Institute for Development Economics Research (UNU/WIDER) was established by the United Nations University as its first research and training centre and started work in Helsinki, Finland in 1985. The purpose of the Institute is to undertake applied research and policy analysis on structural changes affecting the developing and transitional economies, to provide a forum for the advocacy of policies leading to robust, equitable and environmentally sustainable growth, and to promote capacity strengthening and training in the field of economic and social policy making. Its work is carried out by staff researchers and visiting scholars in Helsinki and through networks of collaborating scholars and institutions around the world.

UNU World Institute for Development Economics Research (UNU/WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

Camera-ready typescript prepared by Liisa Roponen at UNU/WIDER
Printed at UNU/WIDER, Helsinki

ISSN 1609-5774
ISBN 952-455-136-5 (printed publication)
ISBN 952-455-137-3 (internet publication)