European Commission

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Analysing the European ICT Poles of Excellence: Case Studies of Inner London East, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn

JRC-IPTS/DG CONNECT joint project Nr. 31786-2010-06

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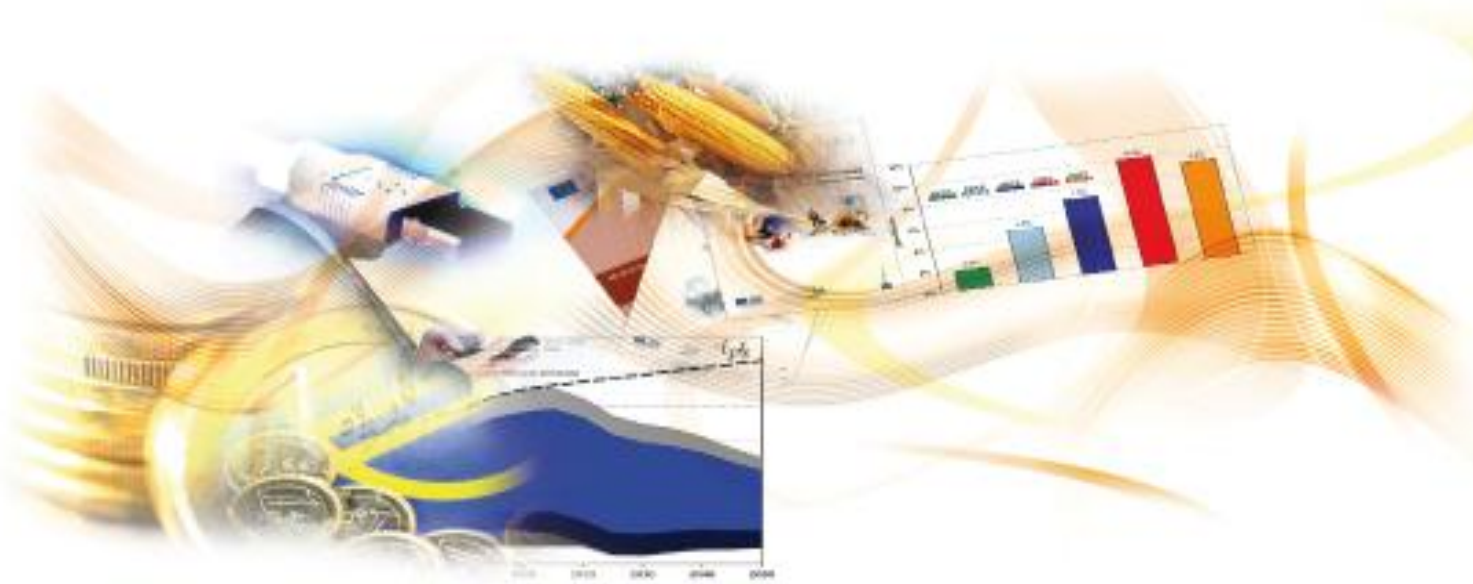
2014



Report EUR 26428 EN

Joint Research Centre

European Commission
Joint Research Centre
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JRC85354

EUR 26428 EN

ISBN 978-92-79-35066-5 (pdf)

ISSN 1831-9424 (online)

doi:10.2791/63309

Luxembourg: Publications Office of the European Union, 2014

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Printed in Spain

Acknowledgments

This analysis was produced by the Information Society Unit at the European Commission's Joint Research Centre - Institute for Prospective Technological Studies for DG Communications Networks, Content and Technology (Project Nr 31786-2010-06). It is part of the project: "European ICT Poles of Excellence" (EIPE) jointly funded by DG CONNECT and JRC-IPTS. The authors wish to thank and acknowledge the following experts and colleagues for their valuable input and comments: Zoe Kay (DG CONNECT), Jean-Paul Simon (JPS Consulting), Andrea De Panizza (OECD), Marc Bogdanowicz (JRC-IPTS), Paul Desruelle (JRC-IPTS) and all the participants at the EIPE Expert Workshop, Seville, 11-12 November 2010. Finally, thorough checking and editing of the text by Patricia Farrer is gratefully acknowledged.

How to cite this publication

Please cite this publication as:

Nepelski, D. and De Prato, G. (2014) 'Analysing the European ICT Poles of Excellence. Case studies of Inner London East, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn', JRC Scientific and Policy Reports - EUR 26428 EN. Seville: JRC-IPTS.

Preface

The European ICT Poles of Excellence (EIPE) research project is a joint project of DG CNECT and the JRC Institute for Prospective Technological Studies (Project Nr 31786-2010-06). It investigated the issues of growth, jobs and innovation, which have become the main priorities of the European Union's growth strategy programme 'Europe 2020'. The overall objectives of the EIPE project are to set the general conceptual and methodological conditions for defining, identifying, analysing and monitoring the existence and progress of current and future EIPE, in order to develop a clear capacity to distinguish these among the many European ICT clusters, observe their dynamics and offer an analysis of their characteristics.

The EIPE project spanned the period between 2010 and 2013. Over this time, it developed a tool based on a database of original ICT activity indicators, which was enriched with geographical information to allow localisation and aggregation at NUTS 3. The tool helps to answer such questions as:

- How is ICT R&D, innovation and economic activity distributed in Europe?
- Which locations are attracting new investments in the ICT sector?
- What is the position of individual European locations in the global network of ICT activity?

The EIPE project had four main steps (see **Figure 1**). First, European ICT Poles of Excellence were defined. Second, a statistical methodology to identify EIPE was elaborated. Third, the empirical mapping of EIPE was performed and fourth, an in-depth analysis of five NUTS 3 regions was undertaken. This work was documented in a series of EIPE reports:

- Defining European ICT Poles of Excellence. A Literature Review,
- Identifying European ICT Poles of Excellence. The Methodology,
- Mapping the European ICT Poles of Excellence. The Atlas of ICT Activity in Europe.
- Analysing the European ICT Poles of Excellence. Case studies of Inner London East, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn.
- Key Findings and Implications of the European ICT Poles of Excellence project.

Figure 1: Overview of the EIPE project

STEP	Defining European ICT Poles of Excellence	Methodology to identify EIPE	Mapping EIPE	Zooming-in at the European ICT landscape
INPUT	Literature Review Taking stock of existing initiatives and case studies	Elaboration of indicators Identification of data sources Composite indicators	4 composite indicators based on 42 indicators on ICT R&D, Innovation and Business for the whole Europe at NUTS 3 level	Detailed information on ICT activity in Inner East London, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn
OUTPUT	Definition of European ICT Poles of Excellence	Methodology to identify EIPE	Atlas of European ICT activity	An in-depth analysis of 5 key ICT locations in Europe
EIPE Report	1	2	3	4

More information on the European ICT Poles of Excellence (EIPE) project can be found at:
http://is.jrc.ec.europa.eu/pages/ISG/EIPE.html

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1. Introduction

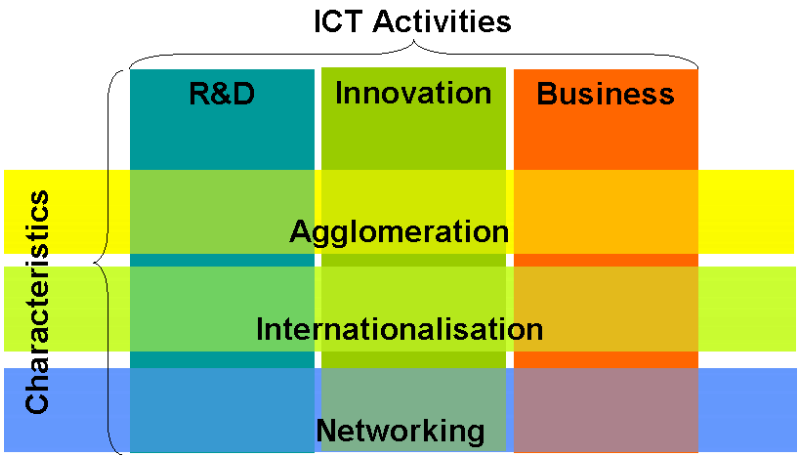
This report is the fourth EIPE Report and presents case studies of five selected European regions. It builds on the previous 3 reports, which have led to the definition of EIPE (Nepelski et al. 2013), elaboration of the methodology for empirical identification of EIPE (De Prato and Nepelski 2013a) and, finally, empirical mapping of ICT activity in Europe (De Prato and Nepelski 2013b).

EIPE are defined as:

> **European ICT Poles of Excellence (EIPE) are geographical agglomerations of best performing Information and Communication Technologies production, R&D and innovation activities, located in the European Union, that exert a central role in global international networks.**

Following this definition, an empirical framework has been elaborated, which is presented in **Figure 2**.

Figure 2: Empirical framework to identify ICT Poles of Excellence



The present report offers a case-study level investigation of 5 EIPEs. In order to provide a more thorough analysis of five EIPEs, it presents and interprets the data collected during course of the project to understand the actual facts, context and story of each location, i.e. its R&D, innovation and business activity. Each case study gives a detailed picture of the type of activity and actors located in each EIPE organized along the methodological dimensions (activities and characteristics) described in **Figure 2** and further explained in the second EIPE Report on methodology (De Prato and Nepelski 2013a). This exercise is meant to cast more light on the type of activity and actors in each location and to reveal their strengths and weaknesses. This information will give a better overview of the ICT environment in each of the locations and will help us to understand their role in the European ICT landscape.

Using the information collected in the third EIPE Report (De Prato and Nepelski 2013b), **Table 1** shows the EIPE ranking for the 30 top NUTS3 regions according to the EIPE composite indicator (EIPE CI). The current report attempts to give a detailed overview of ICT-related activity in the following five regions:

- Inner-London East (UKI12),
- Paris (FR101),
- Kreisfreie Stadt Darmstadt (DE711),
- Dublin (IE021),
- Byen Kobenhavn (DK011).

The first two of the above regions have been identified as first layer EIPE, among the top 4 (EIPE CI >80). The remaining three were identified as high ranking (among the top 30) but diversely (41<EIPE CI<80) ranked.

Table 1: Inner London East, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn in the EIPE ranking

Level	EIPE Rank	NUTS3 Code	Region name	EIPE CI
1st tier	1	DE212	Munchen, Kreisfreie Stadt	100
	2	**UKI12**	**Inner London - East**	**97**
	3	**FR101**	**Paris**	**95**
2nd tier	4	DE122	Karlsruhe, Stadtkreis	80
	5	UKH12	Cambridgeshire CC	78
	6	SE110	Stockholms lan	77
	7	**DE711**	**Darmstadt, Kreisfreie Stadt**	**73**
	8	FI181	Uusimaa	70
	9	NL414	Zuidoost-Noord-Brabant	70
	10	NL326	Groot-Amsterdam	64
	11	BE242	Arr. Leuven	61
3rd tier	12	DEA22	Bonn, Kreisfreie Stadt	59
	13	FR105	Hauts-de-Seine	59
	14	ITC45	Milano	59
	15	DE300	Berlin	58
	16	**IE021**	**Dublin**	**57**
	17	DEA21	Aachen, Kreisfreie Stadt	55
	18	NL333	Delft en Westland	55
	19	UKJ14	Oxfordshire	51
	20	UKM25	Edinburgh, City of	51
	21	DE111	Stuttgart, Stadtkreis	50
	22	DE125	Heidelberg, Stadtkreis	49
	23	DE21H	Munchen, Landkreis	49
	24	BE100	Arr. de Bruxelles-Capitale	48
	25	**DK011**	**Byen Kobenhavn**	**48**
	26	UKJ11	Berkshire	48
	27	AT130	Wien	47
	28	ES300	Madrid	46
	29	UKJ23	Surrey	45
	30	DE712	Frankfurt am Main, Kreisfreie Stadt	44
	31	UKJ33	Hampshire CC	43
	32	DE252	Erlangen, Kreisfreie Stadt	42
	33	FR103	Yvelines	42
	34	DED21	Dresden, Kreisfreie Stadt	41

Note: The table includes the ranking of 34 best scoring out of 1303 European NUTS 3 regions, i.e. scoring above 41 points on the EIPE Composite Indicator. 1st Tier regions score between 81 and 100, 2nd tier regions between 61 and 80 and 3rd tier regions between 41 and 60 on the EIPE CI. The scale of the EIPE Composite Indicator represents a normalized scale with minimum 0 and maximum 100. The EIPE raw indicator is a z-scores indicator computed over equally weighted 42 indicators. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

Figure 3 shows the performance of each of the regions in the EIPE ranking according to the overall EIPE composite indicator and to the individual dimensions based on the normalised scale between 0 and 100. This is presented in the context of the top 40 regions in each category, in order to show: 1) the main details behind the performance of each region; 2) what regions perform better or worse

than the selected ones; 3); what is the relative distance between them; and 4) how this performance changes for each type of ICT activities.

Regarding the five regions selected for an in-depth analysis, **Figure 3** shows that Inner London East, Paris and Kreisfreie Stadt Munchen rank very high. There is a large gap between these three regions and those that follow. For example, Kreisfreie Stadt Darmstadt came 7th and scored 72. Dublin and Byen Kobenhanv have much lower scores, i.e. 57 and 48, although their overall place in the ranking is 16th and 24th respectively. In addition to showing how scarce and concentrated excellence in ICT activities is (De Prato and Nepelski 2013b), **Figure 3** reveals how large the gap between the top performers and those that follow.

According to **Figure 3**, the performance of the individual regions across the three dimensions is unbalanced. For example, whereas Inner London East ranks top in ICT Business activity, it performs much less well in ICT R&D and ICT Innovation activities. A similar pattern can be observed for Kreisfreie Stadt Darmstadt and the reverse for Paris. Out of the five regions, Dublin has the most balanced performance across the three dimensions.

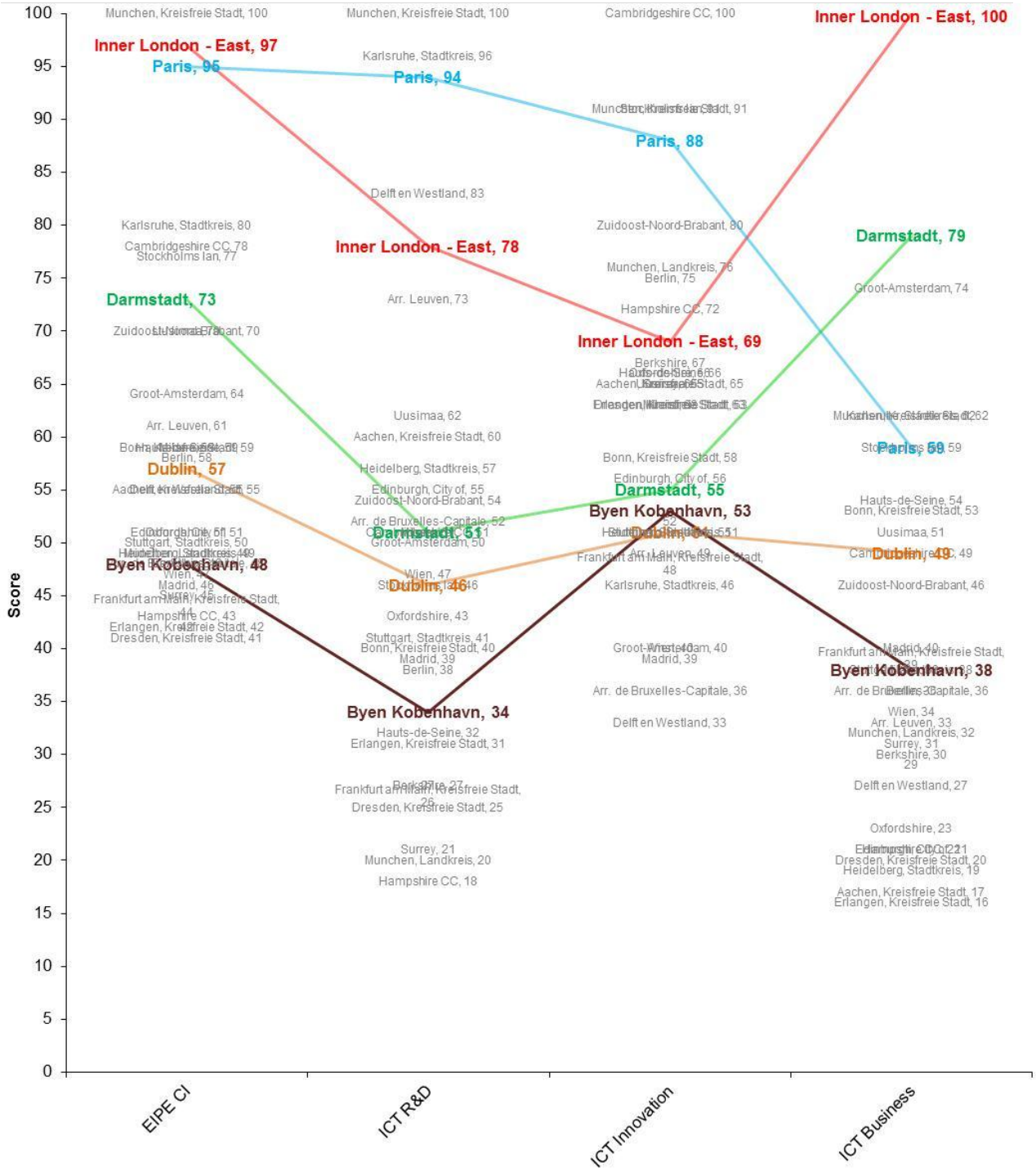
All this gives some hints as to the composition and details of the European ICT landscape. In particular, it shows how different and unique each location is and that all of them have their strengths and weaknesses. These differences motivate the current report which aims to reveal the details behind ICT activity in each of the selected locations. Taking stock of individual elements and building blocks of the ICT environment in Paris or Dublin should help us to better understand their character. This, in turn, should facilitate our understanding of the role they play in the European and global ICT value chain.

The following chapters cast light on the characteristics of ICT activity in each of these locations by revealing any further information that is immediately available for each of the 42 indicators (see the full list of indicators in Section 0 and data sources in Section 0). Full methodological documentation is given in the second EIPE Report (De Prato and Nepelski 2013a).

This report is complemented by four separate reports, which summarise the contributions of various experts from four case-study locations (London, Paris, Dublin and Copenhagen) about the presence and role of public policies in the emergence and the sustainability of the ICT activity in the region.[1]

[1] More information on the European ICT Poles of Excellence (EIPE) project can be found at: http://is.jrc.ec.europa.eu/pages/ISG/EIPE.html

Figure 3: Inner London East, Paris, Darmstadt, Dublin and Byen Kobenhavn in the EIPE ranking



Note: The graph represents the performance of the top 34 regions, i.e. scoring at least 41 points on the EIPE CI, among 1303 EU NUTS 3 regions according to the overall EIPE ranking and their performance according to the individual sub-indicators, i.e. ICT R&D, ICT Innovation and ICT Business ranking. The scale represents a normalized scale with maximum 100 and minimum 0. The EIPE ranking is composed of altogether 42 indicators grouped into three dimensions: ICT R&D, ICT Innovation and ICT Business. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

2. Inner London East

This case study presents and analyses the available data gathered throughout the EIPE study about **Inner London East** (code UKI12). It is a NUTS3 level[2] region of Europe. It corresponds to the eastern part of a broader region, Inner London, a NUTS 2 level region which shows the highest level GDP per capita in Europe (Eurostat, 2013).

The map hereafter shows the Greater London area (UKI). In its centre appears Inner London (UKI 1), composed itself of **Inner London East** (12) and West (11).

Inner London East, shown in the map below, is composed of several boroughs: Hackney, Islington, Lambeth, Lewisham, Newham, Southwark, Tower Hamlets. It has a population of 2 million people.

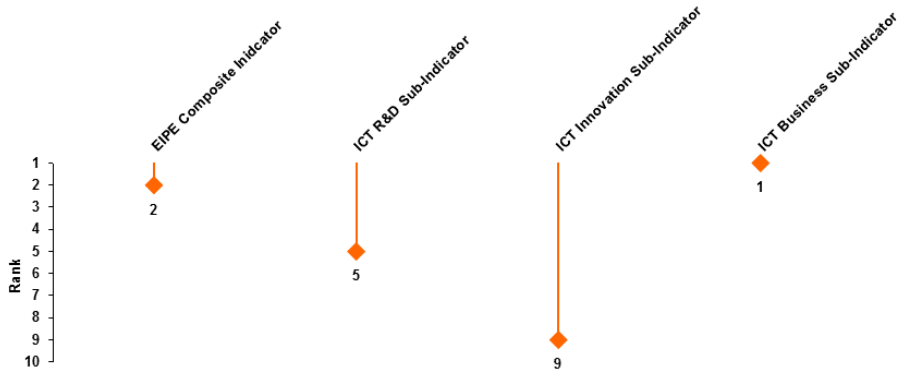
Henceforth, the report often uses the term "London" to refer to Inner London East.

[2] Nomenclature of Territorial Units for Statistics (NUTS). For a list of the European statistical regions see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction.
Source of the map: Wikipedia.

2.1 Inner London East in the EIPE ranking

Inner-London East (UKI12), henceforth London, reached the 2nd place among 1303 regions in Europe according to the EIPE composite indicator (Figure 4). This is only surpassed by Kreisfreie Stadt Munchen (see Figure 3). Figure 4 shows London's position by individual sub-indicators. According to this information, London comes 5th in R&D, 9th in innovation and 1st in business activity ranking.

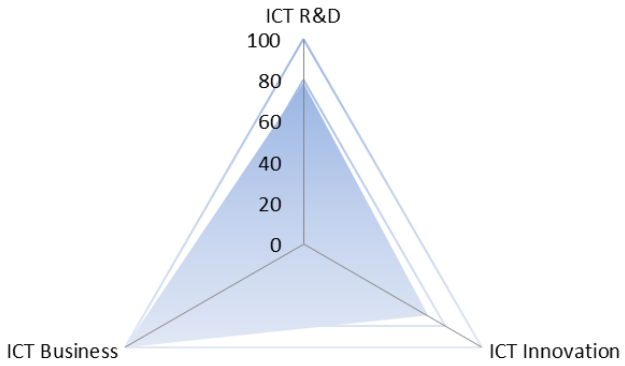
Figure 4: London in the EIPE ranking by EIPE composite indicator, ICT R&D, Innovation and Business sub-indicators



Note: The graph shows the performance of Inner London East in the overall EIPE ranking and the ICT R&D, ICT Innovation and ICT Business ranking. The scale represents the rank in comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

Its relative performance in all three domains, i.e. ICT R&D, ICT Innovation and ICT Business is depicted in **Figure 5**. This figure shows that Inner London East, in comparison with the remaining 1302 EU NUTS 3 regions, is particularly strong in ICT Business activities and less strong in ICT R&D and ICT Innovation activities.

Figure 5: Performance of London in ICT R&D, Innovation and Business



Note: The graph shows the performance of Inner London East in the ICT R&D, ICT Innovation and ICT Business rankings. The scale represents normalized scores with maximum 100 and minimum 0. The rankings are based on the analysis of 1303 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

A more detailed picture of London's rankings in each of the 42 indicators, i.e. the London EIPE ID card, is presented in Table 2. In the following sections, information for each of these indicators is given. Thus, a detailed picture of ICT activity in London, fully based on the data collected during the study to construct the 42 indicators, is offered.

Table 2: London EIPE ID card

Activity	Characteristic	Name of Indicator	Indicator ID	Rank
R&D	Agglomeration	Universities ranked in the QS University Ranking	AgRD 1	18
		Academic ranking of a Computer Science faculty	AgRD 2	7
		Employer ranking of a Computer Science faculty	AgRD 3	3
		Citations ranking of a Computer Science faculty	AgRD 4	6
		R&D expenditures by ICT firms	AgRD 5	7
		ICT FP7 funding	AgRD 6	18
		ICT FP7 participations	AgRD 7	17
		ICT FP7 funding to SMEs	AgRD 8	18
		ICT FP7 participations by SMEs	AgRD 9	17
		Location of ICT R&D centres	AgRD 10	314
		Ownership of ICT R&D centres	AgRD 11	16
		Scientific publications in Computer Science	AgRD 12	4
	Internationalisation	Outward ICT R&D internationalisation	IntRD 1	16
		Inward ICT R&D internationalisation	IntRD 2	260
	Networking	Degree in ICT R&D network	NetRD 1	4
		Closeness centrality in ICT R&D network	NetRD 2	4
		Betweenness centrality in ICT R&D network	NetRD 3	7
		Eigenvector centrality in ICT R&D network	NetRD 4	5
Innovation	Agglomeration	Investment in intangibles by ICT firms	AgIn 1	15
		Venture Capital financing to ICT firms	AgIn 2	1
		ICT patents	AgIn 3	372
	Internationalisation	International co-inventions	IntIn 1	561
	Networking	Degree in ICT innovation network	NetIn 1	50
		Closeness centrality ICT innovation network	NetIn 2	30
		Betweenness centrality ICT innovation network	NetIn 3	76
		Eigenvector centrality ICT innovation network	NetIn 4	11
Business	Agglomeration	Location of ICT Scoreboard Headquarters	AgBuss 1	20
		Ownership of ICT Scoreboard affiliates	AgBuss 2	6
		Location of ICT Scoreboard affiliates	AgBuss 3	1
		Location of ICT firms	AgBuss 4	1
		ICT employment	AgBuss 5	5
		Growth in ICT employment	AgBuss 6	82
		Turnover by ICT firms	AgBuss 7	5
		Growth in turnover by ICT firms	AgBuss 8	1264
		New business investments in the ICT sector	AgBuss 9	2
	Internationalisation	Outward ICT business internationalisation	IntBuss 1	27
		Inward ICT business internationalisation	IntBuss 2	2
	Networking	In-degree in ICT business network	NetBuss 1	1
		Out-degree in ICT business network	NetBuss 2	5
		Closeness centrality in ICT business network	NetBuss 3	2
		Betweenness centrality in ICT business network	NetBuss 4	4
		Eigenvector centrality in ICT business network	NetBuss 5	1

Note: The table reports the performance of Inner London East in each out of the 42 indicators used in the EIPE ranking and grouped around three dimensions, i.e. ICT R&D, ICT Innovation and ICT Business. The scale represents the rank in the comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

2.2 ICT R&D

This section sheds light on London's performance in ICT R&D activities by making use of the information collected in the EIPE project. This analysis follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. Detailed background information on the ranking of London by the R&D indicators listed in this region's EIPE ID card can be found in Table 2. The next sections analyse ICT R&D activities in London by looking at their following characteristics:

- ICT R&D Agglomeration (AgRD), i.e. performance of universities and research organisations; private and public ICT R&D expenditures and the location of ICT R&D centres (Section 0),
- ICT R&D Internationalisation (IntRD), i.e. the number of ICT R&D centres located outside the UK that are owned by companies with headquarters located in London (outward internationalisation) and the number of ICT R&D centres located in London that are owned by foreign companies (inward internationalisation) (Section 0),
- ICT R&D Networking (NetRD), i.e. linkages formed by research organizations located in London when they participate in joint ICT FP7 programmes with organizations located in other regions (Section 0).

2.2.1 ICT R&D Agglomeration (AgRD)

The analysis of the ICT R&D Agglomeration in London starts by providing a snapshot on the universities and the bibliometric output of organizations located in the region (see **Table 3**). This information is based on the QS World University Rankings (reference year 2008) and the Thomson Reuters Web of Knowledge (reference years 2000-2012). For the methodology of indicators construction see Section 0.

London has five universities included in the QS ranking, i.e. London School of Economics and Political Science, Goldsmiths, University of London, King's College London, University College London and Queen Mary, University of London. Taking into account London's share of the total EU population, London ranks 18th for universities among all European regions.

A closer look at the specific performance of individual computer science faculties shows that in comparison with faculties of this kind in other European regions, it ranks between 3rd and 7th respectively for the employer ranking (LSE) and the academic ranking, University College London).

As regards the indicator "scientific publications in Computer Science", the research organisations based in London produced over 10400 publications (8% of EU total) between 2000 and 2012 (as registered by Thomson Reuters). Considering London's share in the EU population, it comes 4th in this indicator in the EU ranking. Among the organizations that produced more than 1000 publications are University of London, Imperial College London, College London and Kings College London.

Table 3: ICT R&D Agglomeration: Universities & bibliometrics

Indicator ID	Name of indicator	Rank	London universities in QS university ranking	
AgRD 1	**Universities ranked in the QS University Ranking**	18	• London School of Economics and Political Science • Goldsmiths, University of London • King's College London • University College London • Queen Mary, University of London	
			The best performing Computer Science faculty of a London university according to the ...	
AgRD 2	**Academic ranking of a Computer Science faculty**	7	University College London	
AgRD 3	**Employer ranking of a Computer Science faculty**	3	London School of Economics and Political Science	
AgRD 4	**Citations ranking of a Computer Science faculty**	6	Goldsmiths, University of London	
AgRD 12	**Scientific publications in Computer Science**	4	**Total number of publications**	**% in EU total**
			10,436	8%
			Research organizations with the highest number of publications, number of publications in brackets	
			• UNIVERSITY OF LONDON (3,537) • IMPERIAL COLLEGE LONDON (1,787) • COLLEGE LONDON (1,314) • KINGS COLLEGE LONDON (1,284)	

Regarding public ICT R&D expenditures, they are proxied here by ICT FP7 funding data attributed to research projects in which private and/or public organizations, based in London, participated in the time period between 2007 and 2011 (see **Table 4**). For the methodology of indicators construction see Section 0.

Given its share in total EU population, London ranks 18th in the EU as regards ICT FP7 funding to organisations. Between 2007 and 2011, organizations based in London received 358 M Euro for ICT FP7 projects. This represents 3.06% of the total EU ICT FP7 funding. Within organizations that received the highest amount of funding are, among others, three universities, i.e. University College of London, Imperial College of Science Technology and Medicine, Queen Mary, University of London and two private companies, i.e. NEC Europe and British Telecommunications. The first one is a Japanese firm, whose EMEA headquarters are located in London, supplying IT Services Business, products essential to the implementation of IT systems and enterprise network systems, equipment required in network implementation to carriers, industrial systems as well as other security-related systems, etc. The second one, i.e. British Telecommunications or BT Group plc, is a British multinational telecommunications services company, employing some 90 000 persons, headquartered in London. It is one of the largest telecommunications services companies in the world and has operations in over 170 countries.

Table 4: ICT R&D Agglomeration: ICT FP7 funding and participation

Indicator ID	Name of indicator	Rank		
AgRD 6	ICT FP7 funding	18	**Total amount of funding (in M of Euro)**	**% in EU total**
			358	3.06%
			Research organizations based in London with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			• UNIVERSITY COLLEGE OF LONDON (50) • IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICIN (33) • NEC EUROPE LTD (32) • QUEEN MARY AND WESTFIELD COLLEGE UNIVERSITY OF LON (25) • BRITISH TELECOMMUNICATIONS (18)	
AgRD 7	ICT FP7 participations	17	**Number of participations**	**% in EU total**
			879	2.94%
			Research organizations based in London with the highest number of participations in ICT FP7 projects, number of participations in brackets	
			• IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICIN (133) • UNIVERSITY COLLEGE LONDON (98) • NEC EUROPE LTD (64) • QUEEN MARY & WESTFIELD COLLEGE (47) • BRITISH TELECOMMUNICATIONS (41)	
AgRD 8	ICT FP7 funding to SMEs	18	**Total amount of funding (in M of Euro)**	**% in EU total**
			68	2.86%
			SMEs based in London with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			• THE SHADOW ROBOT COMPANY LIMITED (2.7) • AVANTI COMMUNICATIONS LIMITED (2.4) • GOV3 LTD (2.1) • IC FOCUS LIMITED (2.1) • Q-SPHERE LIMITED (1.8)	
AgRD 9	ICT FP7 participations by SMEs	17	**Number of participations**	**% in EU total**
			213	2.93%
			SMEs based in London with the highest number of participations in ICT FP7 projects, number of participations in brackets	
			• GLOBAL SECURITY INTELLIGENCE LIMITED (6) • THE SHADOW ROBOT COMPANY LIMITED (6) • GOV3 LTD (5) • IC FOCUS LIMITED (5) • Q-SPHERE LIMITED (5)	

London also ranks 17th among the European regions (again taking into account its share of the total EU population) with respect to the number of participations in ICT FP7 projects. Between 2007 and 2011, organizations based in London participated in 879 ICT FP7 projects. This represents slightly below 3% of all ICT FP7 projects in this period. The organizations that participated in the highest number of ICT FP7 projects were again the same three universities and the two private companies mentioned above. Altogether they participated in over 40% of all the projects granted to organizations based in London.

London, given its share in the total EU population, ranks 18th among all the European regions for the amount of ICT FP7 funding granted to SMEs. Between 2007 and 2011, SMEs based in London received 68 M Euro for ICT FP7 projects. This represents 2.86% of the total EU ICT FP7 funding to SMEs. A similar picture emerges when we look at the number of participations to ICT FP7 project by SMEs based in London. Here, again, one can see that, given its share in the total EU population, London ranks 17th among all the European regions. London's-based SMEs were involved in 213 ICT FP7 projects.

Information on average annual expenditures on R&D by ICT firms and on the location and ownership of ICT R&D centers is used to provide further details on ICT R&D agglomeration (see **Table 5**). Data on the average annual amount spent on R&D in the ICT sector, for the period 2005-2011, originate from the ORBIS database developed by Bureau Van Dijk. Data on the location and ownership of ICT R&D centres[3] is for 2012 and stems from the Design Activity Tool developed by IHS iSuppli, an industry consultancy which specialises in observing the ICT sector. For the methodology of indicators construction see Section 0.

London, given its share of the total EU population, ranks 7th among the European regions with respect to average annual expenditures on R&D by ICT firms. In the period between 2005 and 2011, ICT firms based in London spent on average 1.044 M Euro annually on R&D. This represents 5% of the total EU R&D expenditures by ICT firms.

With the highest R&D budgets, based in London, were, for example, Telit Communications, an enabler of global machine-to-machine (m2m) communication with around 15 M Euro R&D budget, Premier Farnell, an electronic components firm with some 4500 employees and with over 17 M Euro R&D budget, and Allocate Software, a provider of specialist workforce optimisation and corporate governance, risk & compliance software to Defence, Health, Maritime offshore oil and gas and with over 8 M Euro R&D budget.[4]

London has no ICT R&D facilities according to IHS iSuppli definition. Hence, London comes 314th, in this ranking sharing this position with other European regions where there are no such R&D centres.

Instead, however, it can be observed, that in terms of ownership of R&D centres, London ranks 16th. This is due to the fact that major firms, whose headquarters are in London, i.e. BAE Systems, Invensys and Sony-Ericsson, own altogether 39 (5% of the EU total) ICT R&D facilities around the world (7 of which are located in the UK).

BAE Systems plc is a British multinational defence, security and aerospace company headquartered in London, employing close to 100 000 staff worldwide. It is among the world's largest defence contractors; it ranked as the third-largest based on revenues (2011). Its largest operations are in the United Kingdom and United States. The company was formed in 1999 by the £7.7 billion merger of two British companies; Marconi Electronic Systems (MES) – and British Aerospace (BAe) – an aircraft, munitions and naval systems manufacturer.[5]

Invensys, with its Head Offices in London, employs some 20 000 employees and supplies services to four business segments: Software (industrial software for visualisation and supervisory control,

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[3] Those R&D Centres belong to the firms categorised as *major semiconductors influencers* by IHS iSuppli.

[4] Data on R&D expenditures refer to year 2011 and originate from The 2012 EU Industrial R&D Investment Scoreboard.

[5] Adapted from Wikipedia.

process design, simulation and optimisation, real-time operations management and asset management), Industrial Automation (control systems, safety systems and instrumentation), Energy Controls (process, heating, temperature and remote monitoring controls) and Appliance (components and systems that control the operation of appliances). It states having 117 M£ R&D expenditures and an R&D staff of about 1300 (2012 annual report).

Sony-Ericsson, up to 2012 headquartered in London and currently Sony Mobile Communications, is a multinational mobile phone manufacturing company headquartered in Tokyo, Japan, and a wholly owned subsidiary of Sony Corporation. It was founded on October 1, 2001 as a joint venture between Sony and the Swedish telecommunications equipment company Ericsson, under the name Sony Ericsson. Sony acquired Ericsson's share in 2012. Sony Mobile Communications has research and development facilities in Tokyo, Japan; Chennai, India; Lund, Sweden; Beijing, China and Silicon Valley, United States. Sony Mobile is the fourth-largest smartphone manufacturer by market share in the fourth quarter of 2012.

Table 5: ICT R&D Agglomeration: R&D expenditures and R&D centres

Indicator ID	Name of indicator	Rank		
AgRD 5	R&D expenditures by ICT firms	7	**Total amount of funding (in M of Euro)**	**% in EU total**
			1.044	5%
			R&D investors based in London with the highest amount of R&D expenditures	
			• TELIT COMMUNICATIONS PLC • PREMIER FARNELL PLC • ALLOCATE SOFTWARE PLC • ARCONTECH GROUP PLC • TIKIT GROUP PLC	
AgRD 10	Location of ICT R&D centres	314	**Number of R&D centres located in London**	**% in EU total**
			n.a.	n.a.
			Firms with the highest number of R&D centres located in London	
			n.a.	
AgRD 11	Ownership of ICT R&D	16	**Number of R&D centres owned by firms based in London**	**% in EU total**
			39	5%
			Firms based in London with the highest number of R&D centres owned worldwide	
			• BAE Systems • Invensys • Sony-Ericsson	

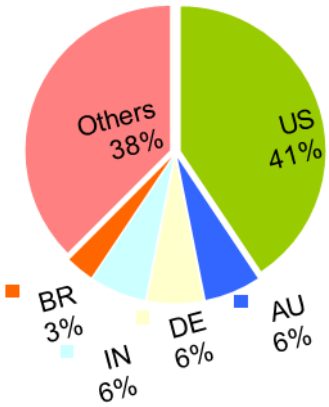
2.2.2 ICT R&D Internationalisation (IntRD)

The analysis of ICT R&D Internationalisation in London is based on data on the location and ownership of R&D centres for 2012 provided by the Design Activity Tool (published by HIS iSuppli, an industry consultancy which specialises in the ICT sector). For the indicator construction methodology, see Section 0.

For the outward ICT R&D internationalisation indicator, London ranks 16th. The indicator is proxied by the number of ICT R&D centres located outside of the UK and that are owned by companies headquartered in London (IHS definition), The companies headquarters based in London (see **Table 6**), own together 32 R&D centres outside of the UK. Their major foreign location for R&D activity is mainly the US.

In terms of inward ICT R&D internationalisation, as there are no foreign-owned R&D facilities identified by IHS iSuppli, London ranks 260th, sharing this position with other European regions where there is no such R&D centres.

Table 6: Outward and inward R&D internationalisation

Indicator ID	Name of indicator	Rank	
InRD 1	Outward ICT R&D internationalisation	16	**Number of ICT R&D centres located outside of the UK that are owned by companies' headquarters located in Inner London East**
			32
			Top locations of R&D centres owned by firms from Inner London East
			
InRD 2	Inward ICT R&D internationalisation	260	**Number of ICT R&D centres located in Inner London East that are owned by foreign companies**
			n.a.
			Origins of companies with R&D centres located in Inner London East
			n.a.

2.2.3 ICT R&D Networking (NetRD)

In order to construct an ICT R&D network and to assess the position of individual regions in it, we rely on data on participation in the ICT part of the ICT FP7 programme. All NUTS3 regions where ICT FP7 ICT R&D programme partners are located are identified as nodes of the network. Bilateral relationships (arcs of the network) between regions exist whenever an organisation from one region participates in an ICT FP7 ICT R&D programme together with an organization from a different region.[6] This allows us to construct a set of network measures for each region and the analysis of these measures for London is presented below.

[6] For more details on the methodology of constructing a network and its application to ICT R&D, see section 0.

Analysing the network of collaborations in the ICT FP7 ICT R&D programme allows us to see London's specific position in the EIPE ranking and better understand its high position and the role it plays in the European ICT landscape.

This analysis focuses on 3 successive steps:

- London's position in the ICT R&D network, as observed from the collaborative links established by the organisations located in London with organisations located in other European regions, and the characteristics of these links,
- The characteristics of the London *ego network*[7] formed by its first degree partners in the ICT R&D network,
- 'London's list of Top 20 partners in the ICT R&D network and the total number of joint projects with each.

For the methodology for indicators construction see Section 0.

London's position in the ICT R&D network

Table 7, which presents London's ranking in the ICT R&D network confirms the rather strong and central role London plays in the ICT R&D network, but with the following nuances:

- London comes 4th out of 761 regions place in the *degree ranking*. This indicator is based on the number of collaborations a given region maintains with other regions in the ICT R&D network. Research organizations based in London participated to a total of 5281 ICT FP7 projects between 2007 and 2012. With those projects, London was directly **connected with 477 other EU NUTS3 regions** (63% of all 761 regions that participated in FP7 ICT R&D). This is, comparatively to other regions, a very high share, only surpassed by 3 regions: Munchen, Paris and Attiki.
- London also comes 4th in the *closeness centrality ranking*. This ranking tells us how well connected a region is in terms of distance from other nodes in the network.[8] It shows that London is **very close** to all remaining 760 regions of the ICT R&D network. Comparatively to other regions, this is a high score, only surpassed by 4 regions, namely: Munchen, Paris, Madrid and Attiki.
- London comes 7th in the *betweenness ranking* which reflects the position of a node as a hub in the network. Thus, London **frequently plays an intermediary role** between other nodes of the ICT R&D network. Comparatively to other regions, this is a high score, surpassed only by few regions such as Attiki and Milano.
- London comes 5th in the *Eigenvector centrality ranking*, reflecting the importance of a region in a network based on the role of its neighbours in the ICT R&D network. This high rank means that London is **connected with other well-connected nodes**, i.e. nodes that themselves play a role of hubs. Comparatively to other regions, this is a high score, only surpassed by 4 regions, namely: Munchen, Paris, Madrid and Attiki.

[7] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

[8] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of links separating the two nodes.

Table 7: London's ranks in the ICT R&D network by network measures

Indicator ID	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	Degree in ICT R&D network	Closeness centrality in ICT R&D network	Betweenness centrality in ICT R&D network	Eigenvector centrality in ICT R&D network
Rank	4	4	7	5

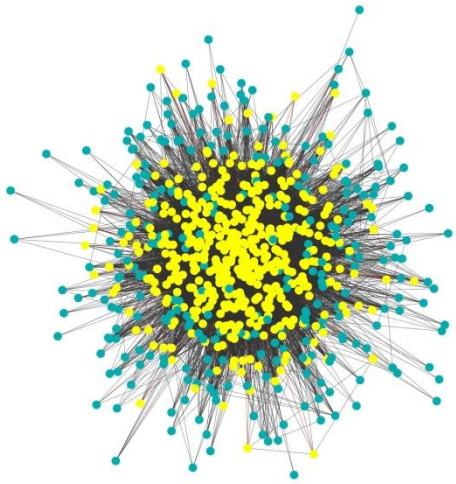
The characteristics of London's ego network

In order to get a deeper insight into the role of London in the ICT R&D network, we have built its *ego network.* London's ego network is a sub-network of the entire ICT R&D network, constructed by taking in account only London's first degree partners (or alters), i.e. nodes directly connected with London and the links among them.[9]

The characteristics of this ego network are then compared with those of the full ICT R&D network to see whether there are some structural differences between the full network and the ego network of the selected node, here London. This way, we can understand better London's neighbourhood in the ICT R&D network and, by casting some light on the attributes of its neighbours, to see how well it is embedded in the ICT R&D network.

An illustration of the full network and its sub-network formed by London's first degree partners (yellow nodes) is given in Figure 6. Table 8 summarises the main measures of the London ego network and compares it to the full ICT R&D network.

Figure 6: The ICT R&D network and the ego network of London



Note: The graph represents the full ICT R&D network as defined in section together with the ego network formed by London's first degree partners represented by yellow nodes.

According to **Table 8**, London's ego network includes 477 individual regions connected directly to London, i.e. 63% of the regions in the full ICT R&D network. Altogether these regions form nearly 23000 linkages, i.e. 83% of the linkages in the entire network. Thus, the fact that only 63% of the regions in the full network account for 83% of all connections indicates that London's neighbours are far better connected than an average node.

[9] Ego networks are also known as the neighbourhood networks or first degree neighbourhoods of ego Everett, M. & Borgatti, S. 2005. 'Ego network betweenness.' *Social Networks,* 27:1, 31-38.

This is also confirmed by the density of London's ego network, which shows how well the network is connected. London's ego network shows a **density**, i.e. a ratio of the actual number of links to the number of possible links, of 0.201, as compared to 0.095 for the full ICT R&D network. Thus, its ego network is significantly denser than the full ICT R&D network.

The **clustering** coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. The score for London's ego network is 0.722 and is slightly smaller than for the full ICT R&D network. This indicates that the regions present in London's ego network are less clustered than the regions present in the full ICT R&D network. Nevertheless, due to the high value of the clustering coefficient observed in the London's ego network, also here regions form tightly connected groups.

The **network centralization** level of an ego network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal are the nodes in terms of their position in the network. London's ego network scores 0.8 whereas the full ICT R&D network scores 0.6: the variation in the nodes' centrality levels in the ego network is significantly higher than in the full network. This means there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network. This might, for example, indicate that there are few nodes with a very central position in the network and numerous nodes that play less central roles.

The **distance**[10] between any two nodes in London's ego network, measured by the average path length, is 1.8, as compared to nearly 2 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT R&D network.

The **average number of direct neighbours** of the regions included in the London's ego network is 96, i.e. over 30% more than it is in the in the full ICT R&D network, where an average node has only 72 partners. Thus, the regions in the London's ego network show a higher level of connectedness as compared to the average in the full network.

Table 8: Characteristics of London's ego network vs. full ICT R&D network

Network-Level Measure	Full ICT R&D network	London's ego network
Node Count	761	478
Link Count	27,490	22,950
Density	0.095	0.201
Clustering Coefficient	0.755	0.722
Network centralization	0.638	0.802
Average path length	1.980	1.799
Average number of neighbours	72	96

London's top partners in the ICT R&D network

Table 9 gives the list of London's top 20 partners in the ICT R&D network and the number of joint projects carried out with each. In addition, the rankings for each partner in the four network measures are given.

[10] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of links separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Of the 477 partners with which London maintains direct connections in the ICT R&D network, relationships with **the top 20 partners account for over 40%** of all the projects in which organisations located in London were involved. This provides evidence for the existence of strong agglomeration forces in the shaping of the ICT R&D landscape.

Regarding the network characteristics of London's top 20 partners, the majority of the projects are conducted with regions which themselves play very strong and central roles in the network. For example, London's main partner in terms of the number of joint projects is Munchen, the key node in the ICT R&D network according to the network measures reported in **Table 9**. The following partners, e.g. Paris, Madrid and Attiki, are similarly important nodes of the network. Thus, besides being itself an important node in the network, London is very strongly connected with the remaining key players of the ICT R&D in Europe.

Table 9: Top 20 partners of London in the ICT R&D network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint projects**	**Share in total**	**Degree in ICT R&D network**	**Closeness centrality in ICT R&D network**	**Betweennes s centrality in ICT R&D network**	**Eigenvector centrality in ICT R&D network**
1	DE212	Kreisfreie Stadt Munchen	215	4.1%	1	1	1	1
2	FR101	Paris	210	4.0%	2	2	2	2
3	ES300	Madrid	189	3.6%	3	3	4	3
4	GR300	Attiki	167	3.2%	4	4	6	4
5	ITC45	Milano	156	3.0%	6	6	5	6
6	ITE43	Roma	154	2.9%	7	7	3	7
7	ES511	Barcelona	117	2.2%	8	8	8	8
8	BE100	Arr. de Bruxelles-Capitale	94	1.8%	10	10	10	11
9	FI181	Uusimaa	93	1.8%	9	9	9	9
10	AT130	Wien	87	1.6%	11	11	11	10
11	DE300	Berlin	80	1.5%	14	14	14	12
12	DE122	Stadtkreis Karlsruhe	75	1.4%	12	12	15	15
13	SE110	Stockholms lan	75	1.4%	15	15	12	14
14	NL326	Groot-Amsterdam	68	1.3%	21	21	21	25
15	BE242	Arr. Leuven	65	1.2%	13	13	13	13
16	FR103	Yvelines	65	1.2%	22	22	32	19
17	HU101	Budapest	63	1.2%	19	19	19	20
18	NL333	Delft en Westland	62	1.2%	18	18	18	21
19	IE021	Dublin	60	1.1%	28	28	26	27
20	GR122	Thessaloniki	59	1.1%	26	26	37	22
Total Top 20			**2154**	**40.8%**				
Total			**5281**	**100%**				

2.3 ICT innovation

This section sheds light on London's performance in the ICT innovation activities. It makes use of the information collected in the EIPE project and follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. To this aim, London's EIPE ID card provides detailed background information on this region's ranking by ICT innovation indicators (Table 2). ICT Innovation activities in London are analysed by looking at the following characteristics:

- ICT Innovation Agglomeration (AgIn), i.e. investment in intangibles by ICT firms, venture capital financing to ICT firms and ICT patents (Section 0),
- ICT Innovation Internationalisation (IntIn), i.e. the number of ICT co-inventions developed by inventors located in London together with inventors located outside of the UK (Section 0),
- ICT Innovation Networking (NetIn) i.e. the place occupied by London in the ICT innovation network formed by all co-inventions jointly developed by inventors located in all regions around the world (Section 0).

2.3.1 ICT Innovation Agglomeration (AgIn)

The analysis of the ICT Innovation Agglomeration in London starts with providing information on the amount of investment in intangibles by ICT firms, venture capital funding to ICT firms and the number of ICT patents issued by inventors residing in London (see **Table 11**). This data comes from the company-level database ORBIS by Bureau Van Dijk (reference years from 2005 to 2012), Venture Source by Dow Jones (reference years from 2000 to 2012) and REGPAT by OECD-EPO (reference years from 2000 to 2012) respectively. For the methodology for indicator construction see Section 0.

London, given its share in the total EU population, ranks 15th among all European regions with respect to average annual ICT firms investment by ICT firms in in intangibles. According to the company-level database ORBIS by Bureau Van Dijk, in the period 2005 - 2011, ICT firms based in London spent on average 7 M Euro annually on intangibles. This represents 1.7% of the total EU investment in intangibles. The ICT firms based in London which invested most in intangibles were, for example, British Telecom; Inmarsat, a satellite telecommunications company; and Misys, a software vendor specializing in software for banking and investment businesses.

Regarding the number of venture capital deals to ICT firms, London ranks 1st among all the EU regions. Between 2000 and 2012, over 2300 VC deals were made with ICT firms based in London. The most prominent examples, in terms of the amount received, include Symbian, a company that created a mobile operating system, Netscalibur, a provider of IP managed services and DigiPlex, a data centre builder and operator.

ICT innovation output is measured here by the number of ICT patents. Organisations based in London produced 378 (0.3% of EU total) patented ICT inventions between 2000 and 2012. Considering London's share in the EU population, this results in a 372nd position in this ranking.

Table 10: ICT Innovation agglomeration in London

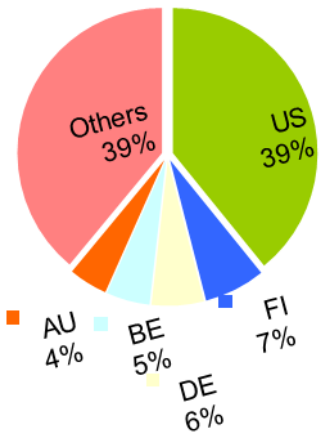
Indicator ID	Name of indicator	Rank		
AgIn 1	Investment in intangibles by ICT firms	15	**Total amount of (in M of Euro)**	**% in EU total**
			7.11	1.72%
			Top investors in intangibles by firms based in London	
			• BT GROUP PLC • COOKSON GROUP PLC • INMARSAT PLC • LAIRD PLC • MISYS PLC	
AgIn 2	Venture Capital financing to ICT firms	1	**Number of VC financial deals to firms based in London**	**% in EU total**
			2,311	8%
			Organizations with the highest amount of VC funding	
			• Symbian • Netscalibur • DigiPlex • CityReach International • Video Networks International	
AgIn 3	ICT patents	372	**Total number of ICT patents**	**% in EU total**
			378	0.3%

2.3.2 ICT Innovation Internationalisation (IntIn)

The analysis of ICT Innovation internationalisation in London is based on the data on ICT international co-inventions, i.e. the number of patents with an inventor residing in London and at least one inventor residing outside of the UK. The data originates from REGPAT (source: OECD-EPO) and covers the period from 2000 to 2012. For the methodology for indicator construction see Section 0.

According to the information presented in Table 11, of the total 378 ICT patented inventions that included London-based inventors, 100 were an output of international collaboration involving residents from outside the UK. This gives London a 561st position in the ranking. The main external partners in ICT co-inventing activity were mainly from the US and with much lower shares from Finland, Germany, Belgium and Austria.

Table 11: ICT innovation internationalisation of London

Indicator ID	Name of indicator	Rank	
IntIn 1	International co-inventions	561	**Number of international ICT co-inventions**
			100
			Top countries by the number of co-inventions between inventors located in London and ...
			

2.3.3 ICT Innovation Networking (NetIn)

In order to construct an ICT innovation network and to assess the position of individual regions in it, we rely on the network analysis of the locations of inventors residing in different regions of the world (3646 regions in total) and jointly developing ICT inventions for which a patent application has been introduced (period 2000-2009. The relationship between two different locations can be described as the total sum of co-inventions developed by inventors residing in these two regions (Guellec and Van Pottelsberghe de la Potterie 2001).

We identify all regions where inventors are located as nodes of the network. Bilateral relationships (arcs of the network) exist between regions whenever an inventor from one region co-developed an invention with an inventor based in a different region.[11] These definitions allow us to construct a set of network measures for each region: the analysis of those measures in the case of London is presented below.

Analysing this network of inventor collaborations in technology development allows us to observe the specific position of London in the ICT innovation network, as compared to other European regions. It also enables us to better understand its position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- London's position in the ICT innovation network, as observed from the collaborative links established by inventors located in London with inventors located in other regions around the world, and the characteristics of these links,

[11] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0.

- The characteristics of the ICT innovation ego network[12] of first degree partners of London,
- London's top 20 partners in the ICT innovation network and the number of inventions patented jointly with each.

For the methodology of indicators construction see Section 0.

London's position in the ICT innovation network

Table 12, which presents London's ranking in the ICT innovation network shows that London is among the most central nodes in the ICT innovation network, but not among the leading ones. In particular:

- London comes 50th by the degree indicator out of 1189 European regions (and 3646 regions in total, worldwide) in the ICT innovation network, This indicator is based on the number of collaborations a given region maintains with other regions in the ICT innovation network with altogether 3646 regions worldwide through joint co-inventions in the period between 2000 and 2009. It is directly **connected with 277 regions** (8% of the all regions worldwide) that participate in the ICT innovation network. The degree ranking indicator is based on the number of collaborations a given region maintains with other regions in a given network.
- London also comes 30th in the closeness centrality ranking among the European regions. This ranking tells us how well connected a region is in terms of distance[13] to other nodes in the network. London is shown to be **very close** to the remaining regions of the ICT innovation network. In addition, considering that the level of closeness centrality is much higher than the degree level, it can be expected that London is connected to nodes that are themselves very well connected and embedded in the ICT innovation network.
- London comes 76th in the betweenness ranking, a ranking that reflects the position of a node as a hub in the network. London has an important **intermediary role** between other nodes of the ICT innovation network, as compared to the remaining European regions.
- London is on the 11th place in the Eigenvector centrality ranking, reflecting the importance of London based on the role of its neighbours in the ICT innovation network**.** London is **connected with other well-connected nodes**. This, together with the high rank in the closeness centrality shows that London is very well connected to the key players in the ICT innovation network.

Table 12: London's rankings in the ICT innovation network by network measures

Indicator ID	NetIn 1	NetIn 2	NetIn 3	NetIn 4
Indicator Name	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweenness centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
Rank	50	30	76	11

[12] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

[13] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of links separating the two nodes.

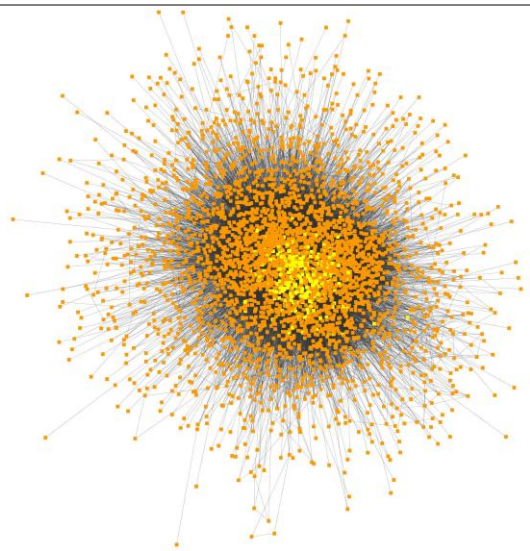
The characteristics of London's ego network

In order to get a deeper insight into the role of London in the ICT innovation network, we have constructed its ego network, i.e. a network consisting of London (ego), the actors it is connected to (alters) and all the links between these alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, London ego network is constructed by taking into account only London's first degree partners, i.e. nodes directly connected with London and the links between them.

The characteristics of this ego network are compared with those of the full ICT innovation network to see whether there are some structural differences between the full network and the one of the selected node, London, and its direct partners. This comparison will help us to understand better London position in the ICT innovation network. In addition, by casting some light on its neighbours' attributes, it will allow us to see how well the region's neighbourhood network is embedded in the ICT innovation network.

An illustration of the full ICT innovation network and its sub-network formed by London first degree partners (yellow nodes) is given below. **Table 13** summarises the main measures of the London ego network and compares it to the full ICT innovation network.

Figure 7: The ICT innovation network and the ego network of London



Note: The graph represents the full ICT innovation network together with the ego network formed by London's first degree partners represented by yellow nodes.

According to **Table 13**, London's ego network includes 278 individual regions connected directly to London, i.e. almost 8% of the regions present in the full worldwide ICT innovation network. Altogether these regions form over 10,000 linkages, i.e. around 10% of the linkages in the entire network. Thus, the fact that only 8% of the network regions account for 10% of its total connections indicates that London's neighbours are slightly better connected than an average node. This is also confirmed by the density measure, i.e. a ratio of the actual number of links to the number of possible links, which shows how well the network is connected. London's ego network shows a **density** of 0.269, as compared to 0.014 for the full ICT innovation network. Thus, the ego network is significantly denser than that of the full ICT innovation network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. London's ego network scores 0.612 which is significantly higher

than that of the worldwide ICT innovation network. This indicates that the regions present in London's ego network are clustered into more tightly connected groups as compared to the regions present in the worldwide ICT innovation network.

The **network centralization** level of an ego network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. For the London's ego network, it scores 0.736, as compared to 0.3 for the full ICT innovation network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network in terms of their position in the network. This might, for example indicate, that there are few nodes with very central position in the network and numerous nodes that play less central roles. This is confirmed by the composition of London's top 20 partners presented in **Table 14**.

The **distance**[14] between any two nodes in the London's ego network, measured by the average path length, is 1.7, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT innovation network.

The **average number of direct neighbours** of the regions included in the London's ego network is 74, i.e. over 40% more than in the in the full ICT innovation network, where an average node has only 52 partners. This confirms that the regions in the London's ego network show a higher level of connectedness than the average in the full network.

Table 13: London's ego network vs. full ICT innovation network

Network-Level Measure	Full ICT innovation network	London's ego network
Node Count	3,646	278
Link Count	94,689	10,350
Density	0.014	0.269
Clustering Coefficient	0.499	0.612
Network centralization	0.320	0.736
Average path length	2.676	1.731
Average number of neighbours	51.941	74.460

Top 20 partners of London in the ICT innovation network

Table 14 lists London's top 20 partners in the ICT innovation network, showing the number of joint patents. In addition, the four network measures are ranked for each partner. Because the list of partners also includes non-EU regions, the ranks of the neighbours are given for the whole network, i.e. including non-EU regions. Hence, this way, the ranks presented here are not comparable with the ranking of the EU regions.

Of the 277 partners with which London maintains direct connections in the ICT innovation network, the relationships with **the top 20 partners account for 72%** of all the co-patents between innovators located in London and other regions. This provides evidence for the existence of strong agglomeration forces that are present in the shaping of the ICT R&D landscape.

[14] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Regarding London's top 20 partners, it can be seen that that the majority of the inventors who work together with London's inventors are located in regions that are located near London. For example, the major partners in terms of the number of joint patents include Inner London West and Outer London West and Hertfordshire. Among the top 20 partners of London in the ICT innovation network, only three are from the outside of the UK and one from the outside of Europe, namely, Uusimaa (FI181), New York County, NY (US36061), Põhja-Eesti (EE001).

Thus, unlike in the ICT R&D network presented in section 0, the intensity of the interaction is less related to the partner's position in the network and more to its geographical proximity. At the same time, however, one needs to keep in mind that the current network includes over 3600 nodes worldwide, among which 1200 in Europe. Hence, having a number of partners in the first top 100 in the degree level indicates that London's partners play a strong role in the ICT innovation network.

Table 14: London's Top 20 partners in the ICT innovation network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint patents**	**Share in total**	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweennes s centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
1	UKI11	Inner London - West	21.70	17%	63	71	87	148
2	UKI23	Outer London - West	14.04	11%	78	97	130	176
3	UKH23	Hertfordshire	10.07	8%	96	98	145	228
4	UKI21	Outer London - East	5.16	4%	248	257	594	303
5	UKJ23	Surrey	5.10	4%	67	75	76	144
6	UKI22	Outer London - South	4.97	4%	240	297	449	313
7	UKH33	Essex CC	4.30	3%	153	135	229	296
8	UKH12	Cambridgeshire CC	3.98	3%	21	36	35	112
9	UKH14	Suffolk	3.47	3%	200	252	113	335
10	UKJ33	Hampshire CC	2.76	2%	29	46	50	114
11	UKJ11	Berkshire	2.62	2%	87	95	134	177
12	UKJ13	Buckinghamshire CC	2.55	2%	184	166	336	282
13	UKJ14	Oxfordshire	1.89	1%	54	74	85	137
14	FI181	Uusimaa	1.49	1%	93	106	67	316
15	UKJ42	Kent CC	1.22	1%	299	272	391	288
16	UKJ24	West Sussex	1.08	1%	353	322	420	337
17	US36061	New York County, NY	1.06	1%	25	28	45	13
18	UKM22	Clackmannanshire and	0.96	1%	522	472	600	428
19	UKK13	Gloucestershire	0.92	1%	336	290	363	307
20	EE001	Põhja-Eesti	0.87	1%	1094	880	957	1917
Total Top 20			**90.20**	**72%**				
Total nr of joint patents			**126.15**	**100%**				

2.4 ICT Business

This section sheds light on London's performance in the ICT business activities by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. Detailed background information on the region's rankings for the ICT business indicators is presented in Table 2 (London's EIPE ID card). ICT business activities are analysed by looking at the following characteristics:

- ICT Business Agglomeration (AgBuss), i.e. location of ICT Scoreboard companies and their affiliates, location of ICT firms, employment and turnover of ICT firms and new investments in the ICT sector (Section 0),
- ICT Business Internationalisation (IntBuss), i.e. the number of affiliates located outside of the UK that are owned by ICT Scoreboard companies located in London (outward internationalisation) and the number of affiliates located in London that are owned by foreign ICT Scoreboard companies (inward internationalisation) (Section 0),
- ICT Business Networking (NetBuss), i.e. the position of London in a network formed through linkages between regions around the world based on the location and ownership of ICT Scoreboard affiliates (Section 0).

2.4.1 ICT Business Agglomeration (AgBuss)

The analysis of ICT Business Agglomeration in London starts with the key details on the actors based in London (**Table 15**), their economic performance (**Table 16**) and ends with an overview of new investments in ICT in London (**Table 17**).

This information is based on the company-level information provided by ORBIS by Bureau Van Dijk (reference years from 2005 to 2012)[15] and data collected in the European Investment Monitor by Ernst&Young for the period 1997-2011. For the methodology for indicator construction see Section 0.

Table 15: ICT Business Agglomeration in London

Indicator ID	Name of indicator	Rank		
AgBuss 1	Location of ICT Scoreboard Headquarters	20	**Number of ICT Scoreboard Headquarters located in London**	**% in EU total**
			11	5%
			ICT Scoreboard Headquarters located in London	
			• Actix International • ARC International • Brit Insurance • BT • Inmarsat • Invensys • Misys • Psion • Smith & Nephew • Telit Communications • Ubiquisys	
AgBuss 2	Ownership of ICT Scoreboard affiliates	6	**Number of ICT Scoreboard affiliates owned worldwide by ICT Scoreboard firms headquartered in London**	**% in EU total**
			1058	8%
AgBuss 3	Location of ICT Scoreboard affiliates	1	**Number of ICT Scoreboard affiliates located in London**	**% in EU total**
			1373	11%
AgBuss 4	Location of ICT firms	1	**Number of ICT firms located in London**	**% in EU total**
			147	12%

[15] The information available about business actors that is used here is the following: Location of ICT Scoreboard Headquarters, number of affiliates owned worldwide by ICT Scoreboard Headquarters based in the observed region, number of ICT Scoreboard affiliates located in the observed region and belonging to any of the ICT Scoreboard Headquarter and, finally, number of ICT firms located in the region.

London, given its share of the total EU population, London ranks 20th among EU regions for the number of ICT Scoreboard Headquarters it hosts. This is due to the presence of 11 firms that are on the list of the world's top 637 ICT R&D investors. Among these firms are, for example, Ubiquisys, Psion and British Telecom. Altogether, these 11 ICT Scoreboard firms own above 1000 affiliates worldwide (8% of all affiliates owned by EU ICT Scoreboard firms). This, given London's share in the total EU population, gives it the 6th position in that ranking.

With respect to the affiliates of the 637 ICT Scoreboard Headquarters, 1373 subsidiaries are in London. In other words, 11% of business affiliates belonging to any ICT Scoreboard Headquarter and based in the EU, are located in London. London occupies the 1st place in this ranking. The same situation can be observed for the ranking concerning the location of ICT firms. According to the ORBIS company-level database by Bureau Van Dijk, there are 147 ICT businesses in London (12% of EU total).[16]

The above mentioned ICT firms based in Inner London East provide 6% of the total EU ICT employment and generate over 9% of total EU ICT turnover (see **Table 16**). Bearing in mind London's share in the total EU population, this puts the region on the fifth place in these rankings. Still, London ranks considerably lower on business dynamics, i.e. growth in employment and turnover. With 0% growth in employment and decrease of turnover by ICT firms in the period 2005-12, London ranks 82 and 1264 respectively among all the EU Nuts 3 regions.

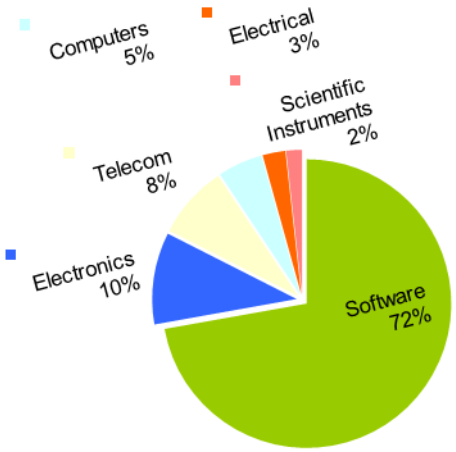
Table 16: ICT Business Agglomeration in London, cont.

Indicator ID	AgBuss 5	AgBuss 6	AgBuss 7	AgBuss 8
Indicator Name	**ICT employment**	**Growth in ICT employment**	**Turnover by ICT firms**	**Growth in turnover by ICT firms**
Rank	5	82	5	1264
% in EU total / %	6.18%	0%	9.46%	-10%

According to the information provided by the European Investment Monitor, between 1997 and 2011, there were 1136 new investments in London by ICT companies (see **Table 17**). This constitutes 10% of all the investments in the entire EU for the period. Given the share of London's population in the total EU population, it comes 2nd in this ranking, after Kreisfreie Stadt Darmstadt. A lion's share of these investments were in the field of software (72%), followed by electronics (10%) and telecommunications (8%).

[16] In order to avoid double-counting, separate searches were run using a filter on consolidation code. In the analysis, companies with consolidated accounts only were selected.

Table 17: ICT Business in Agglomeration London, cont.

Indicator ID	Name of indicator	Rank		
AgBuss 9	New business investments in the ICT sector	2	**Number of new investments in the ICT sector in London**	**% in EU total**
			1136	10%
			Distribution of new investments by activity type	
				

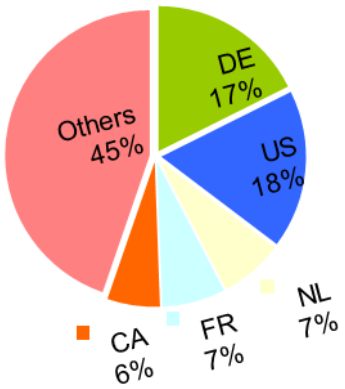
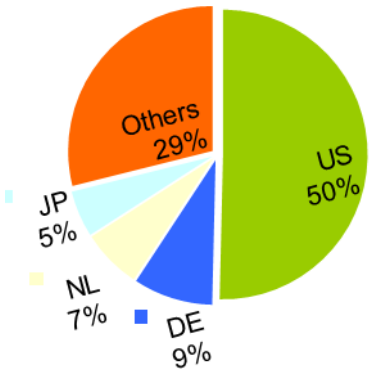
2.4.2 ICT Business Internationalisation (IntBuss)

The analysis of ICT Business internationalisation is based on the data on the location and ownership of affiliates by 637 ICT Scoreboard Headquarters and refers to 2008. This data comes from the company-level information provided by ORBIS by Bureau Van Dijk. Depending on the perspective, two types of internationalisation are considered, i.e. outward internationalisation measured by the number of affiliates located outside of the UK that are owned by ICT Scoreboard companies located in London and inward internationalisation measured by the number of affiliates located in London that are owned by foreign ICT Scoreboard companies. For the methodology for indicator construction see Section 0.

London ranks 27th in outward ICT business internationalisation (see **Table 18**). This is due to the fact that the 11 ICT Scoreboard firms headquartered in London, own altogether 184 affiliates (out of 1058) outside of the UK. Their major foreign business activity locations include Germany, the US, the Netherlands, France and Canada.

In terms of inward ICT business internationalisation, London ranks second. According to the information provided in **Table 18**, 487 out of 1373 affiliates located in London which belong to ICT Scoreboard firms are of foreign ownership, i.e. headquartered outside the UK. Half of the 487 foreign affiliates belong to the US ICT Scoreboard firms. Other major owners are based in Germany, the Netherlands and Japan.

Table 18: Outward and inward ICT business internationalisation

Indicator ID	Name of indicator	Rank	
InBuss 1	Outward ICT business internationalisation	27	**Number of affiliates located outside the UK that are owned by ICT Scoreboard Headquarters located in London**
			184
			Top foreign locations of affiliates owned by ICT Scoreboard Headquarters located in London
			
InBuss 2	Inward ICT business internationalisation	2	**Number of affiliates located in London that are owned by ICT Scoreboard Headquarters located abroad**
			487
			Origins of ICT Scoreboard Headquarters with affiliates located in London
			

2.4.3 ICT Business Networking (NetBuss)

In order to construct an ICT business network and to assess the position of individual regions in it, we rely on the network analysis of the locations of ICT Scoreboard companies and their affiliates. This is done by linking a region where an ICT Scoreboard company is based with a region where it has at least one of its affiliates. Thus, we identify regions as nodes of the network where either an ICT Scoreboard company or affiliate is located. Bilateral relationships (arcs of the network) exist

between regions whenever an ICT Scoreboard company owns an affiliate in a different region.[17] This way we illustrate the destination of business expansion of ICT Scoreboard companies and the location of ICT business activities.[18] This allows us to construct a set of network measures for each region: the analysis of these measures in the case of Kreisfreie Stadt Darmstadt is presented below.

Analysing this network of ICT business activity allows us to observe the specific position of Kreisfreie Stadt Darmstadt in it. It also help us to better understand the region's position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- London's position in the ICT business network, as observed from the links established by the location and ownership of ICT Scoreboard affiliates,
- The characteristics of the London's ego network[19] of first degree partners in the ICT business network,
- The list of the Top 20 partners of London in the ICT business network by the total number of outgoing (an affiliate located in London and owned by an ICT Scoreboard company from a different region) and incoming (an affiliate owned by an ICT Scoreboard company located in London and located in a different region) connections.

For the methodology of indicators construction see Section 0.

London's position in the ICT business network

According to Table 19, which presents the ranking of London in the ICT business network, the results show that London is among the most central nodes in the ICT business network. In particular:

- London comes 1st among European regions in the **in-degree** ranking in the ICT business network. This indicator is based on the number of affiliates located in London that belong to any of the ICT Scoreboard companies headquartered outside of London in 2008. In this ranking, London is followed by Madrid, Milano and Munchen.
- London comes 5th among European regions in the **out-degree** ranking in the ICT business network. This indicator is based on the number of regions in which the 11 ICT Scoreboard companies headquartered in London have their business affiliates in year 2008. In this ranking, London follows Groot-Amsterdam, Munchen, Paris and Darmstadt, Kreisfreie Stadt.
- London comes 4th in the **closeness centrality** ranking for the European regions. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. London is shown to be a region that is **very close** to the other regions of the ICT business network and is surpassed only by three regions, namely: Groot-Amsterdam, Stockholm and Paris.

[17] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0. For a full description of the methodology of network analysis and indicators applied, see the EIPE methodology report De Prato, G. & Nepelski, D. 2013a. 'Identifying European ICT Poles of Excellence. The Methodology.' *JRC Scientific and Policy Reports*. Seville: JRC-IPTS.

[18] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's new investment and headquarter is located in the same region.

[19] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

- London comes 2nd in the **betweenness ranking**, which reflects the position of a node as a hub in the network. London has a very strong **intermediary role** between other nodes of the ICT business network, as compared to the remaining European regions. It is surpassed only by Munchen.
- London comes 1st in the **eigenvector centrality** ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT business network**.** London is **connected with other well-connected nodes**. In this ranking, London is followed by such NUTS 3 regions as: Groot-Amsterdam, Dublin, Paris and Dusseldorf Kreisfreie Stadt.

Table 19: London's rankings in the ICT business network by network measures

Indicator ID	NetRD 1	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	**In-degree in ICT business network**	**Out-degree in ICT business network**	**Closeness centrality in ICT business network**	**Betweenness centrality in ICT business network**	**Eigenvector centrality in ICT business network**
Rank	1	5	4	2	1

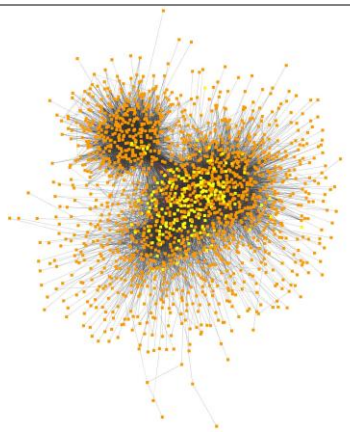
The characteristics of London's ego network

In order to get a deeper insight into the role of London in the ICT business network, we have constructed London's ego network, i.e. a network consisting of London (ego) together with the actors it is connected to (alters) and all the links among those alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, London's ego network is a sub-network of the ICT business network and is constructed by taking in account only London's first degree partners, i.e. nodes directly connected with London and the links between them.

The characteristics of this ego network are compared with those of the full ICT business network to see whether there are structural differences between the full network and that of the selected node, London, and its direct partners. This way, we can understand better London's neighbourhood in the ICT business network and, by casting some light on the attributes of its neighbours, see how well it is embedded in the ICT business network.

An illustration of the full ICT business network and its sub-network formed by London's first degree partners (yellow nodes) is given in Figure 8. Table 20 summarises the main measures of the London ego network and compares this network to the full ICT business network.

Figure 8: The ICT business network and the ego network of London



Note: The graph represents the full ICT business network together with the ego network formed by London's first degree partners represented by yellow nodes.

According to Table 20, London's ego network includes 210 individual regions connected directly to London, i.e. over 11% of the regions in the full ICT business network. Altogether the regions of London's ego network form over 3,200 linkages, i.e. around 18% of the linkages in the entire network. Thus, the fact that the share of nodes is smaller than the share of all connections indicates that London's neighbours are significantly better connected than an average node.

The density measure, i.e. a ratio of the actual number of links to the number of possible links, shows how well the network is connected. London's ego network shows a **density** of 0.13, as compared to 0.01 for the full ICT business network. Thus, London's ego network is significantly denser than that of the full ICT business network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. London's ego network scores 0.536 which is significantly higher than that of the full ICT business network. This indicates that the regions present in London's ego network are clustered into much more tightly connected groups than the regions in the full ICT business network. This may also be a result of the fact that London is connected to generally better connected nodes, which are also well connected among each other.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal are the nodes are in terms of their position in the network. London's ego network scores 0.878, as compared to 0.271 for the full ICT business network: the variation in the nodes' centrality level in the ego network is significantly higher than in the full network. This means there is a greater level of inequality between the nodes in London's ego network than between the nodes in the full network in terms of their position in the network. This might indicate that, for example, in the ego network there are very few nodes with high levels of centrality and numerous nodes that play less central roles.

The **distance**[20] between any two nodes in the London's ego network, measured by the average path length, is 1.9, as compared to 2.8 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT business network.

The **average number of direct neighbours** of the regions included in the London's ego network is 27, i.e. over 45% more than in the in the full ICT business network, where an average node has only 19 partners. This confirms that the regions in the London's ego network show a higher level of connectedness as compared to the average in the full network.

Table 20: Characteristics of London's ego network vs. full ICT business network

Network-Level Measure	Full ICT business network	London's ego network
Node Count	1,840	210
Link Count	18,180	3,244
Density	0.010	0.130
Clustering Coefficient	0.408	0.536
Network centralization	0.271	0.878
Average path length	2.817	1.870
Average number of neighbours	18.641	27.152

[20] The distance between two nodes is given by the shortest path connecting them and it is equal to thenumber of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Top 20 partners of London in the ICT business network by in- and out-degree

Table 21 lists London's top 20 partners in the ICT business network by measures in the ICT business network. The first, i.e. in-degree, tells us about the number of affiliates located in London and owned by ICT Scoreboard companies headquartered in other regions in the world. The second, i.e. out-degree, refers to the number of affiliates owned by ICT Scoreboard companies headquartered in London and located in other regions around the world.

Table 21: London's Top 20 partners in the ICT business network by in- and out-degree

In-degree: Number of affiliates located in London and owned by ICT Scoreboard companies headquartered in …				**Out-degree:** Number of affiliates owned by ICT Scoreboard companies headquartered in London and located in …			
Nr	**Region Code**	**Region name**	**Nr**	**Nr**	**Region Code**	**Region name**	**Nr**
1	US3606	New York County, NY	32	1	IE021	Dublin	15
2	NL326	Groot-Amsterdam	26	2	UKK11	Bristol, City of	11
3	JPD13	Tokyo	26	3	UKH12	Cambridgeshire CC	11
4	IE021	Dublin	21	4	ES300	Madrid	11
5	FR101	Paris	21	5	NL326	Groot-Amsterdam	9
6	3568	SUNNYVALE, US	20	6	FR101	Paris	8
7	3393	SAN JOSE, US	18	7	ITC45	Milano	8
8	UKJ31	Portsmouth	17	8	UKM25	Edinburgh, City of	8
9	US0607	San Bernardino County, CA	17	9	US3606	New York County, NY	7
10	UKJ23	Surrey	16	10	UKJ42	Kent CC	7
11	FR105	Hauts-de-Seine	15	11	NL310	Utrecht	6
12	1699	BILLERICA, US	12	12	DE712	Frankfurt am Main	6
13	2096	DULUTH, US	12	13	FR105	Hauts-de-Seine	5
14	2933	MOUNTAIN VIEW, US	10	14	ES511	Barcelona	5
15	US1914	O'Brien County, IA	10	15	UKJ23	Surrey	4
16	UKH23	Hertfordshire	9	16	UKJ12	Milton Keynes	4
17	AT342	Rheintal-Bodenseegebiet	9	17	LU000	Luxembourg (Grand-Duché)	4
18	UKJ11	Berkshire	8	18	DE212	München, Kreisfreie Stadt	4
19	SE110	Stockholms län	8	19	AT130	Wien	4
20	2868	MINNEAPOLIS, US	8	20	UKJ31	Portsmouth	3
Total top 20			**315** (56% in total)	**Total top 20**			**140** (56% in total)
Total			**563**	**Total**			**249**

Regarding the in-degree ranking, the top 20 regions (of 102 in total) in which there is at least one ICT Scoreboard company with affiliates in London, account for 315 affiliates based in London, i.e. 56% of all ICT Scoreboard affiliates located in London. ICT Scoreboard companies with affiliates in London are from New York County, Groot-Amsterdam and Tokyo, and the majority of the non-European regions are U.S. ones.

Concerning the out-degree ranking, the top 20 regions (of 149 in total) in which there is at least one affiliate of an ICT Scoreboard firm headquartered in London, account for 140 affiliates. These 20 top regions host 56% of the affiliates located outside of London but owned by London's ICT Scoreboard companies. The main business destinations of London ICT Scoreboard companies include Dublin, Bristol, and Cambridgeshire. Although the list is composed of regions outside of the UK, the majority stays within the EU with only one non-EU destination, i.e. New York County, NY, USA.

Thus, while London is an important business destination for ICT Scoreboard companies from around the world – they tend to install affiliates in London - the 11 ICT Scoreboard companies headquartered in London have the majority of their affiliates within the UK or the EU.

2.5 Conclusions

This section summarises the key findings of the EIPE study about the ICT activity in Inner London East, according to the framework depicted in **Figure 2**.

ICT R&D

Concerning the **agglomeration of ICT R&D** activity, London shows a relatively rich image, but with some strong differences across various indicators. There is a large number of universities ranked in the global QS University ranking based in London. Moreover, their scientific output is also high. It is also worth noting, that when surveying the opinion of the business world, Computer Science faculties of London universities are among the leading ones as well. With respect to private R&D infrastructure, it is confirmed that London is a very important place of corporate control of R&D activities, i.e. R&D spending and ownership of R&D centres. However, the region itself does not appear to host those private ICT R&D centres. Also, research organizations based in London are comparatively modest recipients of ICT FP7 funding. This applies also to the participation to FP7 programmes by organizations and SMEs.

Regarding ***ICT R&D internationalisation***, London scores very high on outward internationalisation of ICT R&D, mainly due to the presence of large companies that control a large portion of the ICT R&D activity. The US is the main international location of R&D activities of London-based firms. Other major non-European locations include India and Brazil.

Finally, when looking at ***ICT R&D networking***, London shows to be among the top hubs of the ICT R&D network. Interestingly, its importance comes more from being connected to other key nodes and less from the number of connections. This is mainly a result of the composition of its direct neighbourhood that is composed of other regions that themselves are very well connected and embedded within the global ICT R&D network. As a result, together with its direct partners London forms a densely connected web of linkages that, in practical terms, covers a lion's share of the entire network.

ICT Innovation

With respect to ***ICT Innovation agglomeration***, due to the presence of large ICT firms in London, the region scores high in the ranking of investments in intangibles by ICT firms. This is similar to the picture that emerges when looking at the R&D expenditures (see above). At the same time, London shows a rather low level of innovation as proxied by the number of ICT patent applications. This is of course an expectable consequence of the scarceness of business R&D centres. Nevertheless, the region is a vibrant location in terms of new firms creation and their development. This is exemplified by the fact that London remains Europe's number 1 in terms of venture capital funding. Some of the companies funded in London and financed through VC funds, e.g. Symbian, succeeded in the international markets. Altogether, while London is one of the major locations of business locations and, hence, controls a large share of business expenditures on ICT R&D and intangibles,

the actual research activities are performed outside of the region and this reflects in its overall innovation performance.

Concerning ***ICT Innovation internationalisation***, the level of ICT innovation internationalisation, measured by international co-inventions, is not either exceptionally high. This is due to the above mentioned lack of R&D infrastructure, rather located in the neighbouring regions than in Inner London East itself. Like in the case of R&D internationalisation, inventors from the US account for the highest share of international co-inventions with London-based inventors. Other major countries with which there exists technological collaboration include Finland, Germany and Belgium.

As a result of a its modest performance in ICT Innovation, London does not have a large number of connections with other regions and is not among the key hubs of the ***ICT innovation network***. The majority of London's partners in the ICT innovation network include mainly neighbouring regions in the UK, and some from further locations, e.g. Finland or the US. However, although London is not among the most central European regions in the ICT innovation network and with few connections as compared to other key places of ICT activity in Europe, it is connected with strong nodes in the entire network. Thus, London's importance does not stem from a large number of connections, but rather through being connected to key nodes important in the worldwide innovation network. This way, it keeps very close to the remaining nodes.

ICT Business

ICT Business agglomeration, as expected, confirms that London is one of the key places in Europe and in the world to "do business". This is exemplified by the presence of large firms like numerous ICT Scoreboard firms' headquarters, companies which belong to the world's largest ICT R&D business investors, as well as their affiliates and other ICT firms.

The image of London as a key business location is confirmed by recent trends in business investments. In the last 15 years, London has been among the major recipients of business investments made by ICT firms. The majority of the new ventures were undertaken by firms active in the Software sector. Despite the high scores concerning business activity in London, the growth of employment and turnover generated by the business located in London has been rather low or negative in the recent years. This is most likely to be related to the absolute size of business activity and the resulting limits to (relative) growth for firms that are already large.

The strength of London comes also from the business interactions it maintains with other countries through the presence of foreign firms and the ownership of affiliates located abroad that belong to London-based companies. Thus, consistent with its image as a global business hub, the level of ***ICT Business internationalisation*** of London is very high. In particular, London exhibits a very high level of inward ICT business internationalisation: it attracts companies. Countries with the highest number business of affiliates in London include the US, Germany, the Netherlands and some Asian countries.

Not surprisingly, London is a key hub of the ***ICT Business network***. Above all, its importance is confirmed by a high number of incoming connections, i.e. firms based outside of London having their affiliates in London. The quality and characteristics of these connections make out of London one of the key intermediary nodes in the ICT Business network, i.e. a node that links different parts of the network together. In addition, the strong position of London in this network is also attributed to the high importance of London's direct neighbours.

Summing up, in comparison to all 1303 other NUTS3 regions of Europe, London shows high performance in all three considered dimensions – R&D, Innovation and Business, but with some nuances. As far as observable in the available data, its performance in ICT Business activity is the strongest, i.e. it is number one in Europe. In this category, London outperforms such regions as Kreisfreie Stadt Darmstadt; Groot-Amsterdam; Kreisfreie Stadt Munchen and Stadtkreis Karlsruhe. This is due to the presence of a large number of big multinational companies headquartered in the region and many affiliates of similar firms from around the world. Interestingly, this high score is

also driven by a very high attractiveness of London for Venture Capital funding. London is also a place of corporate ownership and control of R&D activities. These activities, however, are performed outside of London. This explains the lower performance in ICT R&D, as compared to such regions as Kreisfreie Stadt Munchen; Stadtkreis Karlsruhe; Paris and Delft en Westland; and even lower in Innovation activities, as compared to such regions as Cambridgeshire CC; Stockholms lan; Kreisfreie Stadt Munchen or Paris.

Two important features of London need to be underlined. First, its population size – like Munchen and Paris, London is a populated location, with a very high demographic density. Bearing in mind that the population size serves across the whole EIPE exercise to normalise the data, London still comes out at the top of the EIPE ranking, notwithstanding the normalization effect. It is a location of highly intensive ICT activity. A second important feature of ICT activity in London is the fact that it is very well embedded in all types of networks covered within the EIPE analysis. Being central and well-connected in the ICT networks has two implications. One implication concerns the considered node, i.e. in this case London, and the other one the entire network. Regarding London, being central exposes it to a variety of information and ideas that flow between the nodes with which it interacts. This way it is exposed to a range of opportunities and has potential access to resources and capabilities that can be combined with its own resources. Regarding the entire network, by playing the role of a hub, the strength and the quality of London's connections influences the integrity and robustness' of the entire ICT R&D network. This in turn, facilitates the flow of information and the combining of resources present in different parts of the network. All in all, the evidence presented in this chapter confirms consistently that London Inner is part of the tier 1 European ICT Poles of Excellence and hence one of the major location of the ICT European landscape.

3. Paris

This case study presents and analyses the available data gathered throughout the EIPE study about **Paris** (code FR101). It is a NUTS3 level[21] region of Europe.

It is the central part of a broader region, Ile de France (see map), a NUTS 2 level region with the 5th highest level GDP per capita in Europe (Eurostat, 2013).

Paris itself, shown in the map below, is composed of 20 arrondissements. It has a population of around 2.2 million inhabitants.

Henceforth, the report uses the term "Paris" to refer to the NUTS3 level region of Paris.

[21] Nomenclature of Territorial Units for Statistics (NUTS). For a list of the European statistical regions see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction.
Source of the maps: Google maps and Wikipedia.

3.1 Paris in the EIPE ranking

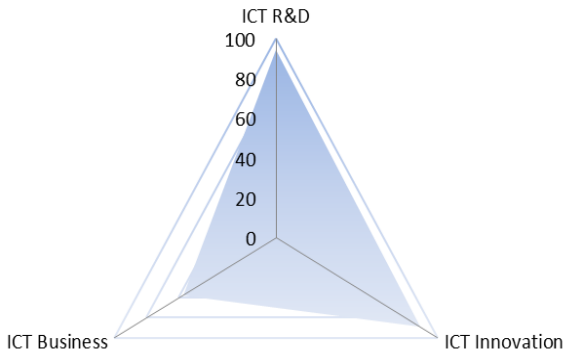
Paris (FR101) reached the 3rd place among 1303 regions in Europe according to the EIPE composite indicator (Figure 9). It is only surpassed by Kreisfreie Stadt Munchen and Inner London East (see Figure 3). Figure 9 shows Paris' position by individual sub-indicators. According to this information, Paris comes 3rd in the R&D, 4th in innovation and 6th in business activity.

Figure 9: Paris in the EIPE ranking by EIPE composite indicator, ICT R&D, Innovation and Business sub-indicators

Note: The graph shows the performance of Paris in the overall EIPE ranking and the ICT R&D, ICT Innovation and ICT Business ranking. The scale represents the rank in comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

Its relative performance in all three domains, i.e. ICT R&D, ICT Innovation and ICT Business is depicted in **Figure 10**. This figure shows that Paris, in comparison with the remaining 1302 EU NUTS 3 regions, is particularly strong in ICT R&D and Innovation activities and, less strong in ICT Business activities.

Figure 10: Performance of Paris in ICT R&D, Innovation and Business



Note: The graph shows the performance of Paris in the ICT R&D, ICT Innovation and ICT Business rankings. The scale represents normalized scores with maximum 100 and minimum 0. The rankings are based on the analysis of 1303 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

A more detailed picture of Paris's rankings in each of the 42 indicators, i.e. the Paris EIPE ID card, is presented in **Table 22**. In the following sections, information for each of these indicators is given. Thus, a detailed picture of the ICT activity in Paris, fully based on the data collected during the study to construct the 42 indicators, is offered.

Table 22: Paris EIPE ID card

Activity	Characteristic	Name of Indicator	Indicator ID	Rank
R&D	Agglomeration	Universities ranked in the QS University Ranking	AgRD 1	37
		Academic ranking of a Computer Science faculty	AgRD 2	8
		Employer ranking of a Computer Science faculty	AgRD 3	8
		Citations ranking of a Computer Science faculty	AgRD 4	4
		R&D expenditures by ICT firms	AgRD 5	3
		ICT FP7 funding to private organisations	AgRD 6	7
		ICT FP7 participations	AgRD 7	7
		ICT FP7 funding to SMEs	AgRD 8	7
		ICT FP7 participations by SMEs	AgRD 9	7
		Location of ICT R&D centres	AgRD 10	78
		Ownership of ICT R&D centres	AgRD 11	4
		Scientific publications in Computer Science	AgRD 12	13
	Internationalisation	Outward ICT R&D internationalisation	IntRD 1	4
		Inward ICT R&D internationalisation	IntRD 2	86
	Networking	Degree in ICT R&D network	NetRD 1	2
		Closeness centrality in ICT R&D network	NetRD 2	2
		Betweenness centrality in ICT R&D network	NetRD 3	2
		Eigenvector centrality in ICT R&D network	NetRD 4	2
Innovation	Agglomeration	Investment in intangibles by ICT firms	AgIn 1	3
		Venture Capital financing to ICT firms	AgIn 2	2
		ICT patents	AgIn 3	49
	Internationalisation	International co-inventions	IntIn 1	121
	Networking	Degree in ICT innovation network	NetIn 1	5
		Closeness centrality ICT innovation network	NetIn 2	5
		Betweenness centrality ICT innovation network	NetIn 3	6
		Eigenvector centrality ICT innovation network	NetIn 4	19
Business	Agglomeration	Location of ICT Scoreboard Headquarters	AgBuss 1	26
		Ownership of ICT Scoreboard affiliates	AgBuss 2	30
		Location of ICT Scoreboard affiliates	AgBuss 3	60
		Location of ICT firms	AgBuss 4	8
		ICT employment	AgBuss 5	2
		Growth in ICT employment	AgBuss 6	82
		Turnover by ICT firms	AgBuss 7	2
		Growth in turnover by ICT firms	AgBuss 8	90
		New business investments in the ICT sector	AgBuss 9	3
	Internationalisation	Outward ICT business internationalisation	IntBuss 1	20
		Inward ICT business internationalisation	IntBuss 2	47
	Networking	In-degree in ICT business network	NetBuss 1	14
		Out-degree in ICT business network	NetBuss 2	3
		Closeness centrality in ICT business network	NetBuss 3	5
		Betweenness centrality in ICT business network	NetBuss 4	3
		Eigenvector centrality in ICT business network	NetBuss 5	4

Note: The table reports the performance of Paris in each out of the 42 indicators used in the EIPE ranking and grouped around three dimensions, i.e. ICT R&D, ICT Innovation and ICT Business. The scale represents the rank in the comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

3.2 ICT R&D

This section sheds light on Paris' performance in ICT R&D activities. It proceeds by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. Detailed background information on the ranking of Paris by the R&D indicators listed in this region's EIPE ID card can be found in **Table 22**. The next sections analyse the ICT R&D activities in Paris by looking at their following characteristics:

- ICT R&D Agglomeration (AgRD), i.e. performance of universities and research organisations; private and public ICT R&D expenditures and the location of ICT R&D centres (Section 0),
- ICT R&D Internationalisation (IntRD), i.e. the number of ICT R&D centres located outside France that are owned by companies with headquarters located in Paris (outward internationalisation) and the number of ICT R&D centres located in Paris that are owned by foreign companies (inward internationalisation) (Section 0),
- ICT R&D Networking (NetRD), i.e. linkages formed by research organizations located in Paris when they participate in joint ICT FP7 programmes with organizations located in other regions (Section 0).

3.2.1 ICT R&D Agglomeration (AgRD)

The analysis of the ICT R&D Agglomeration in Paris starts by providing a snapshot on the universities and the bibliometric output of organizations located in Paris (see **Table 23**). This information is based on the QS World University Rankings (reference year 2008) and the Thomson Reuters Web of Knowledge (reference years 2000-2012). For the methodology of indicators construction see Section 0.

Paris has three universities included in the QS ranking, i.e. École Normale Supérieure, Paris, École Polytechnique and Université Paris 1, Panthéon-Sorbonne. Taking into account the share of Paris in the total EU population, Paris ranks 37th in the university ranking among all European regions.

A closer look at the specific performance of individual computer science faculties shows that in comparison with faculties of this kind in other European regions, it ranks between 4th and 8th respectively for the indicators "citations ranking" (École Normale Supérieure Paris) and "academic and employer ranking" (École Polytechnique).

As regards the indicator "Scientific publications in Computer Science", the research organisations based in Paris produced over 6674 publications (5% of EU total) between 2000 and 2012 (as registered by Thomson Reuters). Considering its share in the EU population, Paris comes 13th in this indicator in the EU ranking. Among the organizations that produced more than 1000 publications are CNRS, INRIA and Université Pierre et Marie Curie.

Table 23: ICT R&D Agglomeration: Universities & bibliometrics

Indicator ID	Name of indicator	Rank	Paris universities in QS university ranking	
AgRD 1	**Universities ranked in the QS University Ranking**	37	1. École Normale Supérieure, Paris 2. École Polytechnique 3. Université Paris 1, Panthéon-Sorbonne	
			The best performing Computer Science faculty of a Paris university according to the …	
AgRD 2	**Academic ranking of a Computer Science faculty**	8	École Polytechnique	
AgRD 3	**Employer ranking of a Computer Science faculty**	8	École Polytechnique	
AgRD 4	**Citations ranking of a Computer Science faculty**	4	École Normale Supérieure, Paris	
AgRD 12	**Scientific publications in Computer Science**	13	**Total number of publications**	**% in EU total**
			6,674	5%
			Research organizations with the highest number of publications, number of publications in brackets	
			1. CNRS (1,811) 2. INRIA (1,039) 3. Université Pierre et Marie Curie (1,006)	

Regarding public ICT R&D expenditures, they are proxied here by ICT FP7 funding data attributed to research projects in which private and/or public organizations, based in Paris, participated in the time period between 2007 and 2011 (see **Table 24**).

Given its share in total EU population, Paris ranks 7th among in the EU as regards ICT FP7 funding to organizations based in Paris. Between 2007 and 2011, organizations based in Paris received 608 M Euro for ICT FP7 projects. This represents over 5% of the total EU ICT FP7 funding. The five organizations that received the highest amount of funding were three universities/research institutes, i.e. Commissariat à l'énergie atomique et aux énergies alternatives, CNRS and Université Pierre et Marie Curie, and two private companies, i.e. France Telecom and Alcatel Thales.

Paris also ranks 7th among the European regions (again taking into account its share in the total EU population) with respect to the number of participations in ICT FP7 projects. Between 2007 and 2011, organizations based in Paris participated in 1423 ICT FP7 projects. This represents slightly below 5% of all ICT FP7 projects in this period. The organizations that participated to the highest number of ICT FP7 projects were again the organisations mentioned above. Altogether they participated in over 40% of all the projects granted to organizations based in Paris.

Paris, given its share in the total EU population, ranks 7th among all the European regions for the amount of ICT FP7 funding granted to SMEs. Between 2007 and 2011, SMEs based in Paris received 107 M Euro for ICT FP7 projects. This represents 4.48% of the total EU ICT FP7 funding to SMEs. A similar picture emerges we look at the number of participations to ICT FP7 project by SMEs based in Paris. Here, again, one can see that, given its share in the total EU population, Paris ranks 7th among all the European regions. Paris-based SMEs were involved in 297 ICT FP7 projects, i.e. slightly above 4% of ICT FP7 projects to which SMEs participated Europe-wide.

Table 24: ICT R&D Agglomeration: ICT FP7 funding and participation

Indicator ID	Name of indicator	Rank		
AgRD 6	ICT FP7 funding	7	**Total amount of funding (in M of Euro)**	**% in EU total**
			608	5.19%
			Research organizations based in Paris with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			1. COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES (144) 2. CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (59) 3. FRANCE TELECOM SA (32) 4. UNIVERSITE PIERRE ET MARIE CURIE (20) 5. ALCATEL - LUCENT BELL LABS France (12)	
AgRD 7	ICT FP7 participations	7	**Number of participations**	**% in EU total**
			1423	4.76%
			Research organizations based in Paris with the highest number of participations in ICT FP7 projects, number of participations in brackets	
			1. COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES (251) 2. CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (168) 3. FRANCE TELECOM SA (79) 4. UNIVERSITE PIERRE ET MARIE CURIE (49) 5. ALCATEL THALES III V LAB (42)	
AgRD 8	ICT FP7 funding to SMEs	7	**Total amount of funding (in M of Euro)**	**% in EU total**
			107	4.48%
			SMEs based in Paris with the highest amount of funding, amount per organization in brackets	
			1. TRIALOG (8.6) 2. ALDEBARAN ROBOTICS (6.2) 3. JCP-CONSULT (4.6) 4. SOFTECO SISMAT SPA (3.9) 5. JCP-CONSULT SAS (3.4)	
AgRD 9	ICT FP7 participations by SMEs	7	**Number of participations**	**% in EU total**
			297	4.09%
			SMEs based in Paris with the highest number of participations in ICT FP7 projects, number of participations in brackets (in M of Euro)	
			1. JCP-CONSULT (16) 2. TRIALOG (16) 3. ALDEBARAN ROBOTICS (14) 4. EVALUATIONS AND LANGUAGE RESOURCES DISTRIBUTION AG (8) 5. EXALEAD SA (8)	

Information on average annual expenditures on R&D by ICT firms and on the location and ownership of ICT R&D centres is used to provide further details on ICT R&D agglomeration (see **Table 25**). Data on the average annual amount spent on R&D in the ICT sector, for the period 2005-2011, originate from the ORBIS database developed by Bureau Van Dijk. Data on the location and ownership of ICT R&D centres[22] is for 2012 and stems from the Design Activity Tool developed by IHS iSuppli, an industry consultancy which specialises in observing the ICT sector.

Table 25: ICT R&D Agglomeration: R&D expenditures and R&D centres

Indicator ID	Name of indicator	Rank		
AgRD 5	R&D expenditures by ICT firms	3	**Total amount of funding (in M of Euro)**	**% in EU total**
			4.339	21%
			R&D investors based in Paris with the highest amount of R&D expenditures	
			1. ALCATEL-LUCENT S.A. 2. FRANCE TELECOM SA 3. SAFRAN 4. VIVENDI 5. PARROT	
AgRD 10	Location of ICT R&D centres	78	**Number of R&D centres located in Paris**	**% in EU total**
			15	2%
			Firms with the highest number of R&D centres located in Paris	
			1. Brose 2. Delphi 3. EADS 4. Hitachi 5. LG Electronics	
AgRD 11	Ownership of ICT R&D	4	**Number of R&D centres owned by firms based in Paris**	**% in EU total**
			157	20%
			Firms based in Paris with the highest number of R&D centres owned worldwide	
			1. Valeo 2. Ingenico 3. Alcatel-Lucent 4. Thales Group 5. Oberthur Technologies	

Paris, given its share in the total EU population, ranks 3rd among the European regions with respect to average annual expenditures on R&D by ICT firms. In the period between 2005 and 2011, ICT firms based in Paris spent on average 4.339 M Euro annually on R&D. This represents 21% of the total EU R&D expenditures by ICT firms. ICT firms with the highest R&D budgets based in Paris were, for example, Alcatel-Lucent, France Telecom, Safran, Vivendi and Parrot.

[22] Those R&D Centres belong to the firms categorised as *major semiconductors influencers* by IHS iSuppli.

Paris hosts 15 R&D facilities identified by IHS iSuppli as *major semiconductor influencers*. Hence, Paris ranks 78th in this comparison. These R&D centres located in Paris belong, among others to such multinational companies, as Brose, Delphi, EADS, Hitachi and LG Electronics.

Looking at the ownership of R&D centres by the major semiconductor influencers (IHS definition) based in Paris, it can be observed, that Paris comes 4th. Companies located in Paris as Valeo, Ingenico, Alcatel-Lucent, Thales Group and Oberthur Technologies own 157 R&D facilities around the world (20% of the EU total).

3.2.2 ICT R&D Internationalisation (IntRD)

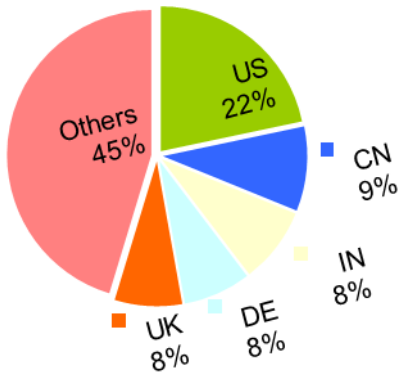
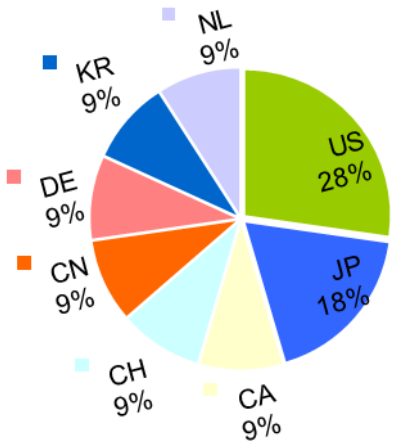
The analysis of ICT R&D Internationalisation in Paris is based on data on the location and ownership of R&D centres for 2012 provided by the Design Activity Tool (published by HIS iSuppli, an industry consultancy which specialises in the ICT sector). For the indicator construction methodology, see Section 0.

The information on ICT R&D internationalisation in Paris is presented in **Table 26**.

For the outward ICT R&D internationalisation indicator, Paris ranks 4th. The indicator is proxied by the number of ICT R&D centres located outside of France and that are owned by companies headquartered in Paris (IHS definition), The companies headquarters based in London (see **Table 25**), own altogether 106 R&D centres outside of France. Their major foreign locations of R&D activity include the US, China, India, Germany and the UK.

In terms of inward ICT R&D internationalisation, which is proxied by the number of ICT R&D centres located in Paris and owned by major semiconductor influencers (IHS definition) located outside of France, Paris ranks 86th. This is due to the fact that the major semiconductor influencers of foreign origins (see **Table 25**), own altogether 11 R&D centres that are based in Paris. The countries of origin of these companies are US, Japan, Canada, Switzerland, China, Germany, Korea and the Netherlands.

Table 26: Outward and inward R&D internationalisation

Indicator ID	Name of indicator	Rank	
InRD 1	Outward ICT R&D internationalisation	4	**Number of ICT R&D centres located outside of France that are owned by companies' headquarters located in Paris**
			106
			Top locations of R&D centres owned by firms from Paris
			
InRD 2	Inward ICT R&D internationalisation	86	**Number of ICT R&D centres located in Paris that are owned by foreign companies**
			11
			Origins of companies with R&D centres located in Paris
			

ICT R&D Networking (NetRD)

In order to construct an ICT R&D network and to assess the position of individual regions in it, we rely on data on participation in the ICT part of the FP7 programme. All NUTS3 regions where FP7 ICT R&D programme partners are located are identified as nodes of the network. Bilateral relationships (arcs of the network) between regions exist whenever an organisation from one region participates in a FP7 ICT R&D programme together with an organization from a different region.[23] This allows us

[23] For more details on the methodology of constructing a network and its application to ICT R&D, see section 0.

to construct a set of network measures for each region and the analysis of these measures for Paris is presented below.

Analysing the network of collaborations in the FP7 ICT R&D programme allows us to see Paris specific position in the EIPE ranking and better understand its high position and the role it plays in the European ICT landscape.

This analysis focuses on 3 successive steps:

This analysis is structured in 3 steps focusing successively on:

- Paris' position in the ICT R&D network, as observed from the collaborative links established by the organisations located in Paris with organisations located in other European regions, and the characteristics of these links,
- The characteristics of Paris ego network[24] formed by its first degree partners in the ICT R&D network,
- Paris's list of Top 20 partners in the ICT R&D network and the total number of joint projects with each.

For the methodology for indicators construction see Section 0.

Paris's position in the ICT R&D network

According to **Table 27**, which presents Paris's ranking in the ICT R&D network confirms the rather strong and central role Paris plays in the ICT R&D network, but with the following nuances:

- Paris comes 2nd out of 761 regions in the degree ranking. This indicator is based on the number of collaborations Paris maintains with other regions in the ICT R&D network. Research organizations based in Paris participated in 7731 ICT FP7 projects between 2007 and 2012. With those projects, Paris was directly **connected with 542 regions** (71% of all 761 regions that participated in FP7 ICT R&D). This is, comparatively to other regions, a very high share, only surpassed by Munchen.
- Paris also comes 2nd in the *closeness centrality ranking*. This ranking tells us how well connected a region is in terms of distance from other nodes in the network.[25] It shows that Pari1 is **very close** to all remaining 760 regions of the ICT R&D network. Comparatively to other regions, this is a high score, only surpassed by 1 region, namely Munchen.
- Paris comes 2nd in the betweenness ranking which reflects the position of a node as a hub in the network and, hence, **frequently plays an intermediary role** between other nodes of the ICT R&D network. Comparatively to other regions, this is a high score, only surpassed by, again, Munchen and followed by Attiki, Milano and Roma.
- Paris comes 2nd in the Eigenvector centrality ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT R&D network**.** Paris is **connected with other well-connected nodes**. Comparatively to other regions, this is a high score, only surpassed by Munchen.

[24] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

[25] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of links separating the two nodes.

Table 27: Paris' ranks in the ICT R&D network by network measures

Indicator ID	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	Degree in ICT R&D network	Closeness centrality in ICT R&D network	Betweenness centrality in ICT R&D network	Eigenvector centrality in ICT R&D network
Rank	2	2	2	2

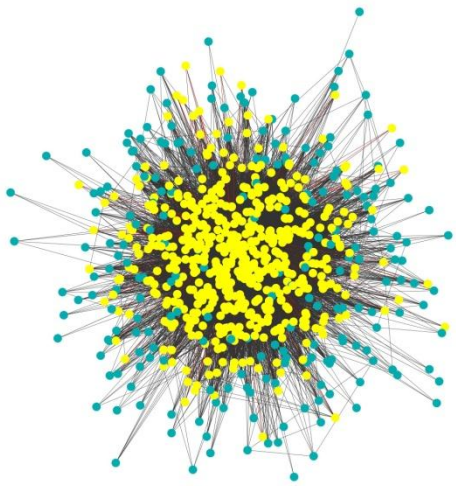
The characteristics of Paris' ego network

In order to get a deeper insight into the role of Paris in the ICT R&D network, we have built its *ego network.* Paris's ego network is a sub-network of the entire ICT R&D network, constructed by taking in account only Paris's first degree partners (or alters), i.e. nodes directly connected with Paris and the links among them.[26]

The characteristics of this ego network are then compared with those of the full ICT R&D network to see whether there are some structural differences between the full network and the ego network of the selected node, here Paris. This way, we can understand better Paris's neighbourhood in the ICT R&D network and, by casting some light on the attributes of its neighbours, to see how well it is embedded in the ICT R&D network.

An illustration of the full ICT R&D network and its sub-network formed by Paris' first degree partners (yellow nodes) is given in **Figure 11**. **Table 28** summarises the main measures of the Paris ego network and compares it to the full ICT R&D network.

Figure 11: The ICT R&D network and the ego network of Paris



Note: The graph represents the full ICT R&D network together with the ego network formed by Paris' first degree partners represented by yellow nodes.

According to **Table 28**, Paris' ego network includes 542 individual regions connected directly to Paris, i.e. 71% of the regions in the full ICT R&D network. These regions form nearly 25 000 linkages, i.e. 90% of the linkages present in the entire network. Thus, the fact that only 71% of the regions in the full network account for 90% of all connections indicates that Paris's neighbours are far better connected than an average node.

[26] Ego networks are also known as the neighbourhood networks or first degree neighbourhoods of ego Everett, M. & Borgatti, S. 2005. 'Ego network betweenness.' *Social Networks,* 27:1, 31-38.

This is also confirmed by the density of the Paris's ego network, which shows how well the network is connected. The Paris's ego network shows a **density**, i.e. a ratio of the actual number of links to the number of possible links, of 0.17, as compared to 0.095 for the full ICT R&D network. Thus, its ego network is significantly denser than that of the full ICT R&D network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. The score of Paris's ego network is 0.719 and is slightly smaller than for the full ICT R&D network. This indicates that the regions in Paris' ego network are less clustered than the regions present in the full ICT R&D network. Nevertheless, due to the high value of the clustering coefficient observed in the Paris's ego network, also here regions form tightly connected groups formed by strongly linked nodes that are then connected to the remaining of the network through the hubs.

The **network centralization** level of a network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. Paris's ego network scores 0.8, whereas the full ICT R&D network scores 0.6. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network. This might, for example indicate, that there are few nodes with very central position in the network and numerous nodes that play less central roles.

The **distance**[27] between any two nodes in Paris's ego network, measured by the average path length, is 1.8, as compared to nearly 2 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than in the full ICT R&D network.

The **average number of direct neighbours** of the regions included in the Paris' ego network is 91, i.e. over 26% more than it is in the in the full ICT R&D network, where an average node has only 72 partners. Thus, Paris's ego network is denser as compared to the average in the full network.

Table 28: Characteristics of Paris's network vs. full ICT R&D network

Network-Level Measure	Full ICT R&D network	Paris's ego network
Node Count	761	543
Link Count	27,490	24,834
Density	0.095	0.169
Clustering Coefficient	0.755	0.719
Network centralization	0.638	0.834
Average path length	1,980	1,831
Average number of neighbours	72	91

Paris' Top 20 partners in the ICT R&D network

Table 29 gives the list of Paris' 20 partners in the ICT R&D network and the number of joint projects carried out with each. In addition, the rankings for each partner in the four network measures are given.

[27] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Of the 542 partners with which Paris maintains direct connections in the ICT R&D network, relationships with **the top 20 partners account for over 40%** of all the projects in which organisations located in Paris were involved. This provides evidence for the existence of strong agglomeration forces in the shaping of the ICT R&D landscape

Regarding the network characteristics of Paris's top 20 partners, the majority of the projects are conducted with regions which themselves play very strong and central roles in the network. For example, the major partner of Paris in terms of the number of joint projects is Munchen, the key node in the ICT R&D network by the network measures reported in **Table 29**. However, Madrid, Attiki and Roma rank high among top partners, while not necessarily being leaders in all network rankings. Berlin and Hauts-de-Seine are other such examples.

Paris is very strongly connected with the remaining key players of the ICT R&D in Europe. However, considering the ranking of its main collaborative partners, it can be said that it is not only the node size and network position that influences Paris' choice of partners, but some other drivers such as, for example, technological complementarity or geographical proximity. The final answer to this question would call for additional research.

Table 29: Top 20 partners of Paris in the ICT R&D network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint projects**	**Share in total**	**Degree in ICT R&D network**	**Closeness centrality in ICT R&D network**	**Betweennes s centrality in ICT R&D network**	**Eigenvector centrality in ICT R&D network**
1	DE212	Kreisfreie Stadt Munchen	390	5.0%	1	1	1	1
2	ES300	Madrid	226	2.9%	3	3	4	3
3	GR300	Attiki	225	2.9%	4	4	6	4
4	ITE43	Roma	212	2.7%	7	7	3	7
5	UKI12	Inner London East	210	2.7%	4	4	7	5
6	ITC45	Milano	198	2.6%	6	6	5	6
7	ES511	Barcelona	170	2.2%	8	8	8	8
8	DE300	Berlin	148	1.9%	14	14	14	12
9	FR105	Hauts-de-Seine	136	1.8%	20	20	25	16
10	FI181	Uusimaa	135	1.7%	9	9	9	9
11	BE242	Arr. Leuven	130	1.7%	13	13	13	13
12	SE110	Stockholms lan	122	1.6%	15	15	12	14
13	FR103	Yvelines	116	1.5%	22	22	32	19
14	AT130	Wien	111	1.4%	11	11	11	10
15	BE100	Arr. de Bruxelles-Capitale	103	1.3%	10	10	10	11
16	NL414	Zuidoost-Noord-Brabant	99	1.3%	17	17	22	17
17	DE122	Stadtkreis Karlsruhe	95	1.2%	12	12	15	15
18	ITC11	Torino	94	1.2%	16	16	16	18
19	NL333	Delft en Westland	94	1.2%	18	18	18	21
20	HU101	Budapest	85	1.1%	19	19	19	20
Total Top 20			**3099**	**40.1%**				
Total			**7731**	**100%**				

3.3 ICT innovation

This section sheds light on Paris performance in the ICT innovation activities. It proceeds by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. To this end, it provides detailed

information on the background information on the ranks of Paris by the ICT innovation indicators included in Paris EIPE ID card in **Table 22**. Thus, it analyses the ICT Innovation activities in Paris by looking at their following characteristics:

- ICT Innovation Agglomeration (AgIn), i.e. investment in intangibles by ICT firms, venture capital financing to ICT firms and ICT patents (Section 0),
- ICT Innovation Internationalisation (IntIn), i.e. the number of ICT inventions developed by inventors located in Paris and outside of France (Section 0),
- ICT Innovation Networking (NetIn) i.e. the place of Paris in the ICT innovation network formed by co-inventions jointly developed by inventors located in regions around the world (Section 0).

3.3.1 ICT Innovation Agglomeration (AgIn)

The analysis of the ICT Innovation Agglomeration in Paris starts with providing information on the amount of investments in intangibles by ICT firms, venture capital funding to ICT firms and the number of ICT patents (see **Table 30**). This data comes from the company level database ORBIS by Bureau Van Dijk (reference years from 2005 to 2012), Venture Source by Dow Jones (reference years from 2000 to 2012) and REGPAT by OECD-EPO (reference years from 2000 to 2012) respectively. For the methodology of indicators construction see Section 0.

With respect to average annual ICT firms investments in intangibles, given its share in the total EU population, Paris ranks 3rd among the European regions. According to the company level database ORBIS by Bureau Van Dijk, in the period between 2005 and 2011, ICT firms based in Paris spent on average 89 M Euro annually on intangibles. This represents 22% of the total EU investments in intangibles by ICT firms. Among ICT firms based in Paris that had the highest investments in intangibles are, for example, France Telecom; Vivendi and Alcatel-Lucent.

Regarding the number of venture capital deals to ICT firms, Paris ranks 2nd among all the EU regions. Between 2000 and 2012, there were over 2133 VC deals that concerned ICT firms based in Paris. The most prominent examples, in terms of the amount received, include Libery Surf, an internet access provider; Sequans Communications SA, a 4G-semiconductor technology company; or FastBooking, a provider of e-marketing and Internet-based technologies for hotels.

Concerning the ICT innovation output measured by the number of ICT patents, organisations based in Paris produced 2762 (2.2% of EU total) patented ICT inventions in the period between 2000 and 2012. Considering Paris's share in the EU population, this results in 49th place in this ranking.

Table 30: ICT Innovation agglomeration in Paris

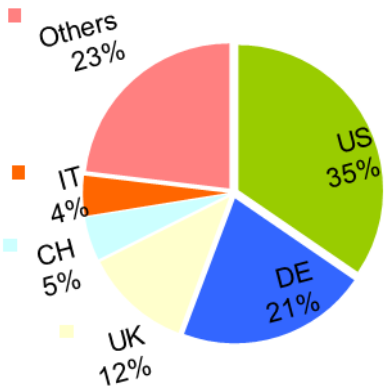
Indicator ID	Name of indicator	Rank		
AgIn 1	Investment in intangibles by ICT firms	3	**Total amount of (in M of Euro)**	**% in EU total**
			89	22%
			Top investors in intangibles by firms based in Paris	
			1. FRANCE TELECOM SA 2. VIVENDI 3. ALCATEL-LUCENT S.A. 4. SAFRAN 5. CAP GEMINI	
AgIn 2	Venture Capital financing to ICT firms	2	**Number of VC financial deals to firms based in Paris**	**% in EU total**
			2,133	8%
			Organizations with the highest amount of VC funding	
			1. Liberty Surf 2. Ceon Corp. 3. Sequans Communications SA 4. Poliris 5. FastBooking	
AgIn 3	ICT patents	49	**Total number of ICT patents**	**% in EU total**
			2,762	2.21%

3.3.2 ICT Innovation Internationalisation (IntIn)

The analysis of ICT Innovation internationalisation in London is based on the data on ICT international co-inventions, i.e. the number of patents with an inventor residing in Paris and at least one inventor residing outside of France. The data originates from REGPAT (source: OECD-EPO) and covers the period from 2000 to 2012. For the methodology for indicator construction see Section 0.

According to the information presented in Table 31, of the total 2762 ICT inventions that included Paris-based inventors, 585 were an output of international collaboration involving residents from outside of France. This gives Paris a 121st place in the current ranking. The main external partners in ICT co-inventing activity of Paris-based inventors were from the US, Germany, the UK, Switzerland and Italy.

Table 31: ICT innovation internationalisation of Paris

Indicator ID	Name of indicator	Rank	
IntIn 1	International co-inventions	121	**Number of international ICT co-inventions**
			585
			Top countries by the number of co-inventions between inventors located in Paris and ...
			

3.3.3 ICT Innovation Networking (NetIn)

In order to construct an ICT innovation network and to assess the position of individual regions in it, we rely on the network analysis of the locations of inventors residing in different regions of the world (3646 regions in total) and jointly developing ICT inventions for which a patent application has been introduced (period 2000-2009. The relationship between two different locations can be described as the total sum of co-inventions developed by inventors residing in these two regions (Guellec and Van Pottelsberghe de la Potterie 2001).

We identify all regions where inventors are located as nodes of the network. Bilateral relationships (arcs of the network) exist between regions whenever an inventor from one region co-developed an invention with an inventor based in a different region.[28] These definitions allow us to construct a set of network measures for each region: the analysis of those measures in the case of Paris is presented below.

Analysing this network of inventor collaborations in technology development allows us to observe the specific position of Paris in the ICT innovation network, as compared to other European regions. It also enables us to better understand its position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Paris's position in the ICT innovation network, as observed from the collaborative links established by inventors located in Paris with inventors located in other regions around the world, and the characteristics of these links,

[28] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0.

- The characteristics of the ICT innovation ego network[29] of first degree partners of Paris,
- Paris's top 20 partners in the ICT innovation network and the number of inventions patented jointly with each.

For the methodology of indicators construction see Section 0.

Paris's position in the ICT innovation network

Table 32, which presents Paris ranking in the ICT innovation network, the results shows that Paris is one of the most central nodes in the ICT innovation network, but with some irregularities. In particular:

- Paris comes 5th out of 1189 European regions (out of 3656 in total worldwide) in the ICT innovation network by the degree indicator. This is based on the number of collaborations a given region maintains with other regions in the ICT innovation network with altogether 3646 regions worldwide through joint co-inventions in the period between 2000 and 2009. Paris is directly **connected with 514 regions** (14% of the all the regions) that participate in the ICT innovation network. This way, Paris is only surpassed by such European regions as Munchen Kreisfreie Stadt, Berlin, Munchen, Landkreis and Cambridgeshire.
- Paris also comes 5th in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Paris is shown to be **very close** to the remaining 3646 regions of the ICT innovation network. Comparatively to other regions, this is a high score, only surpassed by such regions as Munchen Kreisfreie Stadt, Berlin, Munchen Landkreis and Cambridgeshire, and immediately followed by Hampshire, Stockholms lan, Rhein-Neckar-Kreis and Hauts-de-Seine.
- Paris comes 6th in the betweenness ranking, reflecting its position as a hub in the network that **plays a strong intermediary role** between other nodes of the ICT innovation network. Comparatively to other regions, this is a high score, only surpassed by, Munchen Kreisfreie Stadt, Berlin, Stockholms lan, Milano and Munchen Landkreis.
- Paris comes 19th in the eigenvector centrality ranking, reflecting the importance of Paris based on the role of its neighbours in the ICT innovation network**.** Paris is **connected with other well-connected nodes**. The lower score in eigenvector centrality, as compared with the other rankings, might indicate that Paris is connected to less central nodes than those that lead in the eigenvector centrality ranking, i.e. Cambridgeshire, Hampshire, Stockholms lan, Oxfordshire and Surrey.

Table 32: Paris' rankings in the ICT innovation network by network measures

Indicator ID	NetIn 1	NetIn 2	NetIn 3	NetIn 4
Indicator Name	Degree in ICT innovation network	Closeness centrality in ICT innovation network	Betweenness centrality in ICT innovation network	Eigenvector centrality in ICT innovation network
Rank	5	5	6	19

The characteristics of Paris' ego network

In order to get a deeper insight into the role of Paris in the ICT innovation network, we have constructed its ego network, i.e. a network consisting of Paris (ego), the actors it is connected to

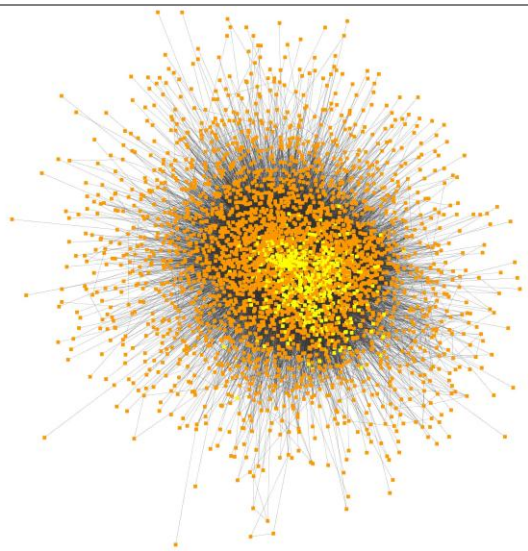
[29] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

(alters) and all the links between these alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Paris ego network is constructed by taking into account only Paris' first degree partners, i.e. nodes directly connected with Paris and the links between them.

The characteristics of this ego network are compared with those of the full ICT innovation network to see whether there are some structural differences between the full network and the one of the selected node, Paris, and its direct partners. This comparison will help us to understand better Paris position in the ICT innovation network. In addition, by casting some light on its neighbours' attributes, it will allow us to see how well the region's neighbourhood network is embedded in the ICT innovation network.

An illustration of the full ICT innovation network and its sub-network formed by Paris first degree partners (yellow nodes) is given in Figure 11. Table 33 summarises the main measures of the Paris ego network and compares it to the full ICT innovation network.

Figure 12: The ICT innovation network and the ego network of Paris



Note: The graph represents the full ICT innovation network together with the ego network formed by Paris' first degree partners represented by yellow nodes.

According to Table 33, Paris' ego network includes 515 individual regions connected directly to Paris, i.e. 14% of the regions present in the full ICT innovation network. Altogether these regions form 23,415 linkages, i.e. 25% of the linkages in the entire network. Thus, the fact that only 14% of the full network regions account for one fourth of its total connections indicates that Paris's neighbours are far better connected than an average node.

This is also confirmed by the density measure, i.e. a ratio of the actual number of links to the number of possible links, which shows how well the network is connected. Paris' ego network shows a **density** of 0.177, as compared to 0.014 for the full ICT innovation network. Thus, the ego network is significantly denser than that of the full ICT innovation network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Paris' ego network scores 0.551 which is slightly higher than that of the full ICT innovation network. This indicates that the regions present in Paris' ego network are clustered in slightly more tightly connected groups as compared to all the regions present in the full ICT innovation network.

The **network centralization** level of a network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of

their position in the network. For the Paris' ego network, it scores 0.826, as compared to 0.3 for the full ICT innovation network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network in terms of their position in the network. This indicates that there are few nodes with very central position in the network and numerous nodes that play less central roles. This was also confirmed by the composition of Paris top 20 partners, i.e. majority of them being close neighbours of the regions which altogether accounted for the majority of the co-patents (see Table 34).

The **distance**[30] between any two nodes in the Paris' ego network, measured by the average path length, is 1.8, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT innovation network.

The **average number of direct neighbours** of the regions included in the Paris' ego network is 90, i.e. over 75% more than in the in the full ICT innovation network, where an average node has only 52 partners. This confirms that the regions in the Paris' ego network show a higher level of density than the average in the full network.

Table 33: Characteristics of Paris's ego network vs. full ICT innovation network

Network-Level Measure	Full ICT innovation network	Paris's ego network
Node Count	3,646	515
Link Count	94,689	23,415
Density	0.014	0.177
Clustering Coefficient	0.499	0.551
Network centralization	0.320	0.826
Average path length	2.676	1.823
Average number of neighbours	51.941	90.932

Top 20 partners of Paris in the ICT innovation network

Table 34 lists Paris's top 20 partners in the ICT innovation network, showing the number of joint patents. In addition, the four network measures are ranked for each partner. Because the list of partners also includes non-EU regions, the ranks of the neighbours are given for the whole network, i.e. including non-EU regions. Hence, this way, the ranks presented here are not comparable with the ranking of the EU regions.

Of the 514 partners with which Paris maintains direct connections in the ICT innovation network, the relationships with **the top 20 partners account for 84%** of all the co-patents between innovators located in Paris and other regions. This provides evidence for the existence of strong agglomeration forces that are present in the shaping of the ICT R&D landscape.

Regarding Paris's top 20 partners, it can be seen that that the majority of the inventors who work together with Paris's inventors are located in regions that are located near Paris. For example, the major partners of in terms of the number of joint patents include Hauts-de-Seine (FR105), Yvelines (FR103) and Essonne (FR104). Among the top 20 partners of Paris in the ICT innovation network, only two are from the outside of France and one of them being from Silicon Valley, i.e. Santa Clara

[30] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

County (US06085) and Konstanz (DE138). Thus, unlike in the ICT R&D network presented in section 0, the intensity of the interaction is less related to the partner's position in the network and more to its geographical proximity. This is also confirmed by the low level of the eigenvector centrality ranking, as compared to the degree centrality (see Table 32).

Table 34: Paris' Top 20 partners in the ICT innovation network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint patents**	**Share in total**	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweennes s centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
1	FR105	Hauts-de-Seine	196.5	25.0%	45	63	53	316
2	FR103	Yvelines	125.0	15.9%	62	86	74	354
3	FR104	Essonne	120.5	15.4%	106	123	117	456
4	FR107	Val-de-Marne	62.4	8.0%	163	173	183	534
5	FR108	Val-d'Oise	32.9	4.2%	303	386	368	677
6	FR102	Seine-et-Marne	17.1	2.2%	317	333	268	724
7	FR106	Seine-Saint-Denis	15.4	2.0%	501	488	721	1100
8	FR714	Isère	14.3	1.8%	71	92	56	233
9	FR523	Ille-et-Vilaine	12.8	1.6%	230	301	180	521
10	FR823	Alpes-Maritimes	9.2	1.2%	127	125	152	290
11	FR824	Bouches-du-Rhône	8.9	1.1%	285	301	248	371
12	FR521	Côtes-d'Armor	8.0	1.0%	558	740	404	807
13	FR222	Oise	6.4	0.8%	697	849	910	1102
14	FR623	Haute-Garonne	5.5	0.7%	232	255	262	426
15	FR242	Eure-et-Loir	5.2	0.7%	1014	870	1246	1464
16	FR251	Calvados	5.1	0.6%	666	796	986	858
17	FR716	Rhône	4.9	0.6%	197	197	171	409
18	US06085	Santa Clara County	4.3	0.6%	1	11	1	16
19	DE138	Konstanz	4.2	0.5%	240	432	583	1317
20	FR301	Nord	3.7	0.5%	400	636	371	662
Total Top 20			662.2	**84%**				
Total nr of joint patents			784.7	**100%**				

3.4 ICT Business

This section sheds light on Paris's performance in the ICT business activities by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. Detailed background information on the region's rankings for the ICT business indicators is presented in **Table 22** (Paris EIPE ID card). ICT business activities are analysed by looking at the following characteristics:

- ICT Business Agglomeration (AgBuss), i.e. location of ICT Scoreboard companies and their affiliates, location of ICT firms, employment and turnover of ICT firms and new investments in the ICT sector (Section 0),
- ICT Business Internationalisation (IntBuss), i.e. the number of affiliates located outside of France that are owned by ICT Scoreboard companies located in Paris (outward internationalisation) and the number of affiliates located in Paris that are owned by foreign ICT Scoreboard companies (inward internationalisation) (Section 0),

- ICT Business Networking (NetBuss), i.e. the position of Paris in a network formed through linkages between regions around the world based on the location and ownership of ICT Scoreboard affiliates (Section 0).

3.4.1 ICT Business Agglomeration (AgBuss)

The analysis of ICT Business Agglomeration in Paris starts with the key details on the actors based in Paris (**Table 35**), their economic performance (**Table 36**) and ends with an overview of new investments in ICT in Paris (**Table 37**).

This information is based on the company-level information provided by ORBIS by Bureau Van Dijk (reference years from 2005 to 2012)[31] and data collected in the European Investment Monitor by Ernst&Young for the period 1997-2011. For the methodology for indicator construction see Section 0.

Paris, given its share in the total EU population, ranks 26th place among the EU regions for the number of ICT Scoreboard company headquarters it hosts. This is due to the presence of 11 firms that are on the list of the world's top 637 ICT R&D investors. Among these firms are, for example, France Telecom and Alcatel-Lucent. Altogether, these 11 ICT Scoreboard firms own 439 (4% of EU total) affiliates located worldwide. This, given Paris' share in the total EU population, gives it the 30th position in that ranking.

With respect to the affiliates of the 637 ICT Scoreboard Headquarters, 226 of them are in Paris. In other words, 2% of business affiliates belonging to any ICT Scoreboard Headquarter and based in the EU, is in Paris. This puts Paris 60th in this ranking. Paris scores higher when considering the location of ICT firms. According to the ORBIS company level database by Bureau Van Dijk, there are 55 ICT businesses located in Paris, i.e. 4.4 % of EU total.[32]

[31] The information available about business actors that is used here is the following: Location of ICT Scoreboard Headquarters, number of affiliates owned worldwide by ICT Scoreboard Headquarters based in the observed region, number of ICT Scoreboard affiliates located in the observed region and belonging to any of the ICT Scoreboard Headquarter and, finally, number of ICT firms located in the region.

[32] In order to avoid double-counting, separate searches were run using a filter on consolidation code. In the analysis, companies with consolidated accounts only were selected.

Table 35: ICT Business Agglomeration in Paris

Indicator ID	Name of indicator	Rank		
AgBuss 1	Location of ICT Scoreboard Headquarters	26	**Number of ICT Scoreboard Headquarters located in Paris**	**% in EU total**
			11	5%
			ICT Scoreboard Headquarters located in Paris	
			1. ESI 2. Radiall 3. Gameloft 4. Sopra 5. France Telecom 6. Alcatel-Lucent 7. GFI Informatique 8. Akka Technologies 9. CS Communication & Systemes 10. Oberthur Technologies 11. Parrot	
AgBuss 2	Ownership of ICT Scoreboard affiliates	30	**Number of ICT Scoreboard affiliates owned worldwide by ICT Scoreboard Headquarters located in Paris**	**% in EU total**
			439	4%
AgBuss 3	Location of ICT Scoreboard affiliates	60	**Number of ICT Scoreboard affiliates located in Paris**	**% in EU total**
			226	2%
AgBuss 4	Location of ICT firms	8	**Number of ICT firms located in Paris**	**% in EU total**
			55	4.4%

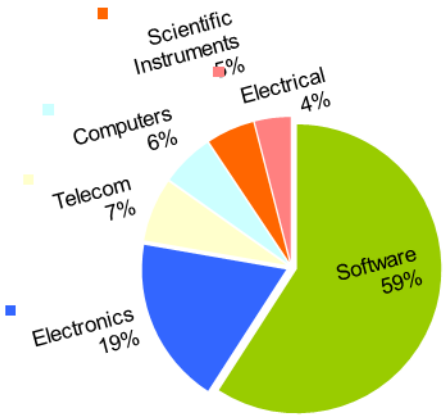
The above-mentioned ICT businesses based in Paris, provide over 23% of the total EU employment and generate over 18% of the EU total turnover of the considered ICT firms (see **Table 36**). Bearing in mind Paris' share in the total EU population, it puts the region on the second place in these rankings. Despite the high position in the rankings based on the size of economic activity, Paris ranks lower once the business dynamics are considered, i.e. growth in employment and turnover. With 0% growth in employment and turnover by ICT firms in the period 2005-12, the French capital ranks 82 and 90 respectively among all the EU Nuts 3 regions.

Table 36: ICT Business Agglomeration in Paris, cont.

Indicator ID	AgBuss 5	AgBuss 6	AgBuss 7	AgBuss 8
Indicator Name	ICT employment	Growth in ICT employment	Turnover by ICT firms	Growth in turnover by ICT firms
Rank	2	82	2	90
% in EU total / %	23.85%	0%	18.03%	0%

According to the information provided by the European Investment Monitor, between 1997 and 2011, there were 822 new investments in Paris by companies from the ICT sector (see **Table 37**). This constitutes 8% of all investments considered in the entire EU. Given the share of Paris' population in the total EU population, it comes 3rd in this ranking. A large share of these investments were in the field of software (59%), followed by electronics (19%) and telecommunications (7%).

Table 37: ICT Business Agglomeration in Paris, cont.

Indicator ID	Name of indicator	Rank		
AgBuss 9	New business investments in the ICT sector	3	Number of new investments in the ICT sector in Paris	% in EU total
			822	8%
			Distribution of new investments by activity type	
				

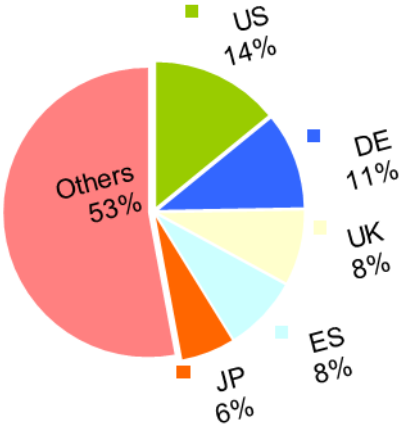
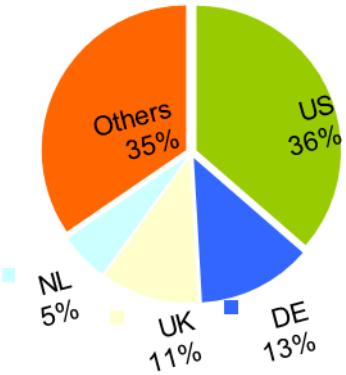
3.4.2 ICT Business Internationalisation (IntBuss)

The analysis of ICT Business Internationalisation is based on the data on the location and ownership of affiliates by 637 ICT Scoreboard Headquarters and refers to 2008. This data comes from the company-level information provided by ORBIS by Bureau Van Dijk. Depending on the perspective, two types of internationalisation are considered, i.e. outward internationalisation measured by the number of affiliates located outside of France that are owned by ICT Scoreboard companies located in Paris and inward internationalisation measured by the number of affiliates located in Paris that are owned by foreign ICT Scoreboard companies. For the methodology for indicator construction see Section 0.

Paris ranks 20th in outward ICT business internationalisation (see **Table 38**). This is due to the fact that the ICT Scoreboard Headquarters based in Paris, own altogether 230 affiliates (out of 439) outside of France. Their major foreign business activity location includes the US, Germany, the UK, Spain and Japan.

In terms of inward ICT business internationalisation, Paris ranks 47th. According to the information provided in **Table 38**, 108 out of 226 affiliates located in Paris which belong to ICT Scoreboard Headquarters are of foreign ownership, i.e. outside of France. 36% of all foreign affiliates belong to the US ICT Scoreboard Headquarters. Other major owners are based in Germany, the UK and the Netherlands.

Table 38: Outward and inward ICT business internationalisation

Indicator ID	Name of indicator	Rank	
InBuss 1	Outward ICT business internationalisation	20	**Number of affiliates located outside of France that are owned by ICT Scoreboard Headquarters located in Paris**
			230
			Top foreign locations of affiliates owned by ICT Scoreboard Headquarters located in Paris
			
InBuss 2	Inward ICT business internationalisation	47	**Number of affiliates located in Paris that are owned by ICT Scoreboard Headquarters located abroad**
			108
			Origins of ICT Scoreboard Headquarters with affiliates located in Paris
			

3.4.3 ICT Business Networking (NetBuss)

In order to construct an ICT business network and to assess the position of individual regions in it, we rely on the network analysis of the locations of ICT Scoreboard companies and their affiliates.

This is done by linking a region where an ICT Scoreboard company is based with a region where it has at least one of its affiliates. Thus, we identify regions as nodes of the network where either an ICT Scoreboard company or affiliate is located. Bilateral relationships (arcs of the network) exist between regions whenever an ICT Scoreboard company owns an affiliate in a different region.[33] This way we illustrate the destination of business expansion of ICT Scoreboard companies and the location of ICT business activities.[34] This allows us to construct a set of network measures for each region: the analysis of these measures in the case of Kreisfreie Stadt Darmstadt is presented below.

Analysing this network of ICT business activity allows us to observe the specific position of Kreisfreie Stadt Darmstadt in it. It also help us to better understand the region's position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Paris' position in the ICT business network, as observed from the links established by the location and ownership of ICT Scoreboard affiliates,
- The characteristics of the ICT innovation ego network[35] of first degree partners of Paris,
- The list of the Top 20 partners of Paris in the ICT business network by the total number of ingoing (an affiliate located in Paris and owned by an ICT Scoreboard company from a different region) and outgoing connections (an affiliate owned by an ICT Scoreboard company located in Paris and located in a different region).

For the methodology of indicators construction see Section 0.

Paris's position in the ICT business network

According to **Table 39**, which presents the ranking of Paris in the ICT business network, the results show that Paris is among the most central nodes in the ICT business network. In particular:

- Paris comes 14th out of 485 European regions in the **in-degree** ranking in the ICT business network. This indicator is based on the number of affiliates located in Paris that belong to any of the ICT Scoreboard companies headquartered outside of Paris in 2008. In this ranking, Paris is surpassed by such regions as: Warszawa (rank 11), Berlin (rank 12) and Praha (rank 13) and is immediately followed by Frankfurt am Main (rank 15), Dusseldorf (rank 16), and Bruxelles-Capitale (rank 17).
- Paris comes 3rd out of 243 European regions in the **out-degree** ranking in the ICT business network. This indicator is based on the number of regions in which ICT Scoreboard companies headquartered in Paris have their business affiliates in year 2008. In this ranking, Paris is surpassed by Groot-Amsterdam and Munchen Kreisfreie Stadt.

  Paris comes 3rd in the closeness centrality ranking among the European regions. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Paris is shown to be a region that is **very close** to the other regions of the ICT

[33] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0. For a full description of the methodology of network analysis and indicators applied, see the EIPE methodology report De Prato, G. & Nepelski, D. 2013a. 'Identifying European ICT Poles of Excellence. The Methodology.' *JRC Scientific and Policy Reports*. Seville: JRC-IPTS.

[34] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's new investment and headquarter is located in the same region.

[35] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

business network and is surpassed by only three regions, namely: Groot-Amsterdam and Stockholms lan.

- Paris comes 5th in the **betweenness ranking** which reflects the position of a node as a hub in the network. Paris has a very strong **intermediary role** between other nodes of the ICT business network, as compared to the remaining European regions. It is surpassed only by Munchen Kreisfreie Stadt, Inner London East, Groot-Amsterdam and Madrid.
- Paris comes 4th in the **Eigenvector centrality** ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT business network**.** Paris is **connected with other well-connected nodes**. In this ranking, Paris is surpassed by such NUTS 3 regions as Inner London East, Groot-Amsterdam and Dublin.

Table 39: Paris's ranks in the ICT business network by network measures

Indicator ID	NetRD 1	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	**In-degree in ICT business network**	**Out-degree in ICT business network**	**Closeness centrality in ICT business network**	**Betweenness centrality in ICT business network**	**Eigenvector centrality in ICT business network**
Rank	14	3	3	5	4

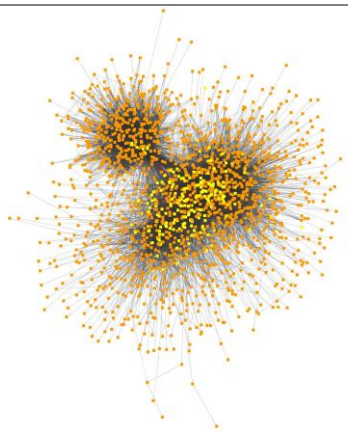
The characteristics of Paris's ego network

In order to get a deeper insight into the role of Paris in the ICT business network, we have constructed Paris's ego network, i.e. a network consisting of Paris (ego) together with the actors it is connected to (alters) and all the links among those alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Paris's ego network is a sub-network of the ICT business network and is constructed by taking in account only Paris's first degree partners, i.e. nodes directly connected with Paris and the links between them.

The characteristics of this ego network are compared with those of the full ICT business network to see whether there are structural differences between the full network and that of the selected node, Paris, and its direct partners. This way, we can understand better Paris's neighbourhood in the ICT business network and, by casting some light on the attributes of its neighbours, see how well it is embedded in the ICT business network.

An illustration of the full ICT business network and its sub-network formed by Paris's first degree partners (yellow nodes) is given in **Figure 13**. **Table 40** summarises the main measures of the Paris ego network and compares this network to the full ICT business network.

Figure 13: The ICT business network and the ego network of Paris



Note: The graph represents the full ICT business network together with the ego network formed by Paris's first degree partners represented by yellow nodes.

According to **Table 40**, Paris's ego network includes 154 individual regions connected directly to Paris, i.e. over 8% of the regions in the full ICT business network. Altogether these regions form over 1,800 linkages, i.e. around 10% of all the linkages in the entire network. Thus, the fact that the share of nodes is slightly smaller than the share of all connections indicates that Paris's neighbour are above average connected than an average node.

The density measure, i.e. a ratio of the actual number of links to the number of possible links, shows how well the network is connected. Paris's ego network has a **density** of 0.14, as compared to 0.01 for the full ICT business network. Thus, Paris' ego network is significantly denser than that of the full ICT business network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Paris's ego network scores 0.6 which is significantly higher than the score for the full ICT business network. This indicates that the regions in Paris's ego network are clustered into much more tightly connected groups than the regions present in the full ICT business network.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. Paris's ego network, it scores 0.862, as compared to 0.271 for the full ICT business network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in Paris's ego network than between the nodes in the full network in terms of their position in the network. This might indicate that, for example, in the ego network there are very few nodes with high levels of centrality and numerous nodes that play less central roles.

The **distance**[36] between any two nodes in the Paris's ego network, measured by the average path length, is 1.9, as compared to 2.8 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT business network.

The **average number of direct neighbours** of the regions included in the Paris's ego network is 21, i.e. over 13% more than in the in the full ICT business network, where an average node has only

[36] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

19 partners. This confirms Paris's ego network is denser as compared to the average in the full network.

Table 40: Characteristics of Paris' network vs. full ICT business network

Network-Level Measure	Full ICT business network	Paris' ego network
Node Count	1,840	154
Link Count	18,180	1,864
Density	0.010	0.138
Clustering Coefficient	0.408	0.600
Network centralization	0.271	0.862
Average path length	2.817	1.862
Average number of neighbours	18.641	21.156

Paris' Top 20 partners in the ICT business network by in- and out-degree

Table 41 lists Paris's top 20 partners in the ICT business network by two measures in the ICT business network. The first one, i.e. in-degree, tells us about the number of affiliates located in Paris and owned by ICT Scoreboard companies headquartered in other regions in the world. The second one, i.e. out-degree, refers to the number of affiliates owned by ICT Scoreboard companies headquartered in Paris and located in other regions around the world.

Regarding the in-degree ranking, the top 20 regions (of 115 in total) in which there is at least one ICT Scoreboard company with affiliates in Paris, account for 188 affiliates based in Paris, i.e. 56% of all ICT Scoreboard affiliates located in Paris. ICT Scoreboard companies with affiliates in Paris are from Hauts-de-Seine, Bristol and Inner London East. The majority of the top 20 regions are European.

Concerning the out-degree ranking, the top 20 regions (of 66 in total) in which there is at least one affiliate of an ICT Scoreboard company headquartered in Paris, account for altogether 78 affiliates. This represents 59% of affiliates owned by Paris ICT Scoreboard companies and located outside of Paris. The main business destinations of Paris ICT Scoreboard companies include Hauts-de-Seine, Inner London East and Sunnyvale. Although the majority of the list is composed of European regions, 9 of them are from the US, e.g. Wayne or San Jose.

Thus, although Paris is the major European business destination among ICT Scoreboard companies from around the world, ICT Scoreboard companies headquartered in Paris have the majority of their affiliates within outside of France and the EU.

Table 41: Top 20 partners of Paris in the ICT business network by in- and out-degree

In-degree: Number of affiliates located in Paris and owned by ICT Scoreboard companies headquartered in ...				Out-degree: Number of affiliates owned by ICT Scoreboard companies headquartered in Paris and located in ...			
Nr	**Region Code**	**Region name**	**Nr**	**Nr**	**Region Code**	**Region name**	**Nr**
1	FR105	Hauts-de-Seine	43	1	FR105	Hauts-de-Seine	10
2	UKK11	Bristol, City of	23	2	UKI12	Inner London East	8
3	UKI12	Inner London East	21	3	3568	SUNNYVALE	6
4	ES300	Madrid	14	4	3751	WAYNE	5
5	BE100	Arr. de Bruxelles-Capitale	12	5	UKJ23	Surrey	5
6	ITC45	Milano	11	6	3393	SAN JOSE	4
7	FR716	Rhône	9	7	FI181	Uusimaa	4
8	DE111	Stuttgart, Stadtkreis	8	8	JPD13	Tokyo	4
9	NL326	Groot-Amsterdam	5	9	BE100	Arr. de Bruxelles-Capitale	3
10	US3606	New York County, NY	5	10	NL326	Groot-Amsterdam	3
11	275	GENEVE	4	11	FR106	Seine-Saint-Denis	3
12	FR106	Seine-Saint-Denis	4	12	IE021	Dublin	3
13	FR107	Val-de-Marne	4	13	SE110	Stockholms län	3
14	FR534	Vienne	4	14	309	MORGES	3
15	FR714	Isère	4	15	3284	REDWOOD CITY	3
16	PL127	Miasto Warszawa	4	16	3730	WASHINGTON	3
17	RO321	Bucuresti	4	17	US3606	New York County, NY	2
18	160	MONTREAL	3	18	FR718	Haute-Savoie	2
19	548	CHIYODA-KU	3	19	UKJ11	Berkshire	2
20	80	SAO PAULO	3	20	US0607	San Bernardino County, CA	2
Total top 20			**188** (56% in total)	**Total top 20**			**78** (59% in total)
Total			**337**	**Total**			**133**

3.5 Conclusions

This section summarises the key findings of the EIPE study about the ICT activity in Paris, according to the framework depicted in **Figure 2**.

ICT R&D

Concerning the **agglomeration of ICT R&D** activity, Paris shows a very rich image, but with some strong differences across various indicators. Paris hosts many universities ranked in the global QS. In addition, their position in the global comparison is very high. For example, the strong position in the citation ranking reflects the high quality of the research conducted in Paris' universities. Paris is also the recipient of a lion's share of ICT FP7 funding among European regions and shows a high participation to ICT FP7 programmes by private companies and SMEs based in Paris. The presence of several large multinational ICT companies make out of Paris an important place of corporate

control of ICT R&D activities (R&D spending and ownership of R&D centres), as it is the case with other global cities, e.g. London. However, as most of the actual R&D takes place outside of Paris, the French capital does not score high in terms of location of ICT R&D activities, as compared to other regions.

In terms of **ICT R&D internationalisation**, Paris holds a very strong position in particular in reaching outward with numerous R&D activities outside Paris and France. However, it scores significantly lower once one considers inward ICT R&D internationalisation: while many R&D centres are owned by companies based in Paris, the French capital city is not among the top regions for hosting French or foreign ICT R&D centres.

Finally, when looking at the **ICT R&D network** position, the French capital shows second, just behind Munich. This very strong position results from being directly connected with nearly two thirds of all the European regions that participate in ICT R&D projects at the European level. Thus, Paris is one of the key players in the ICT R&D landscape in Europe that influences the flow of knowledge between the European regions and the integrity of the ICT R&D network. Due to its central position in the network, Paris can be is one of the few main hubs of the ICT R&D network, among regions such as Kreisfreie Stadt Munchen, Madrid, Attiki, Roma and Inner London East,

ICT Innovation

Regarding **ICT Innovation agglomeration**, Paris hosts a number of multinational large ICT companies: therefore, it scores very high on the investments in intangibles by private businesses. Paris is among the top 50 EU regions in ICT patent intensity, although it is not among the top regions in terms of the number of ICT R&D locations, Finally, inventive activity is also reflected in terms of new firms' creation. Following London, Paris is Europe's number 2 in terms of venture capital funding. The largest firms based in Paris that managed to attract private investments in the last decade are active in such technological fields as, for example, provision of the internet access provider, development of 4G-semiconductor technology or e-marketing and Internet-based technologies.

For **ICT Innovation internationalisation,** as proxied by the number of international co-inventions, Paris scores average. It is not related to the small inventive output: whereas Paris is on the 49th place in terms of the number of patents, it achieved only 121st place on the international co-patenting indicator. Thus, while the inventive performance is a function of the existence of ICT R&D infrastructure, international co-inventing is likely to be related to the international collaborative behaviours of Paris-based inventors. Within the scarce signs of such collaboration, the US, Germany, the UK and Switzerland account for the highest share of international co-inventions with Paris-based inventors.

Paris's position is among the top hubs in the **ICT innovation network** with high scores in nearly all centrality rankings considered. This strong position stems mainly from a large number of connections it holds with other regions. However, once the quality of the connections is considered, i.e. how well Paris' neighbours are connected, the score decreases. This is related to the fact that many of its partners are not among the most important nodes in the network. In practical terms, the most intensive technological collaboration relationships are those with other French regions; strong connections with regions outside of France are rather scarce.

ICT Business

Like other global cities, Paris is among the most important **ICT Business agglomerations** in Europe. This image is however not homogenous once details are considered. For example, although Paris is only on the 20th place in terms of the location of ICT Scoreboard companies, i.e. large ICT R&D spenders, it is Europe's number one in terms of the location of ICT firms and the affiliates of ICT Scoreboard Headquarters. In other words, Paris's ICT business landscape is characterised by the important co-presence of small and medium sized companies with some large global ICT firms. This notwithstanding, the level of employment and turnover generated by ICT firms based in Paris is

very high and, in addition, Paris is an important destination of new business investments by ICT firms (2nd after London). The majority of these investments are done by firms active in such sectors as software, electronics and computer. Like in the case of other large agglomerations of business activity, firms based in Paris do not show exceptionally high growth rates.

Regarding **ICT Business internationalisation**, consistent with its image as a global business hub, the ICT business activity of Paris is very international. However, one can observe different patterns with respect to in- and outward internationalisation. Whereas the former one is rather low - Paris is not among the prime locations for doing business in Europe for foreign companies -, the latter one is considerably higher - companies based in Paris are active in terms of seeking business opportunities outside of France. For example, in Paris there are only 108 affiliates belonging to non-French ICT Scoreboard firms, as compared to 487 affiliates of non-UK ICT Scoreboard in London.

Finally, considering **ICT Business network**, Paris can be considered as one of the hubs of the global ICT business network. However, as noted above, this strong position is mainly driven by the number of outgoing connections that the ICT Scoreboard headquarters based in Paris maintain with other regions. It can also be observed that a number of Paris' neighbours are themselves very important nodes in the ICT business network. This reinforces the role of Paris in the global ICT business network. The list of regions with which Paris has strong business relationships includes a number of ICT hotspots from the US, Europe and Japan. This, as a result, strengthens the position of Paris as an intermediary that links different parts of the network together.

4. Kreisfreie Stadt Darmstadt

This case study presents and analyses the available data gathered throughout the EIPE study about **Kreisfreie Stadt Darmstadt** (code DE711). It is a NUTS3 level[37] region of Europe.

The map hereafter shows the Lander of Hessen (NUTS1: DE7). In its South appears Kreisfreie Stadt Darmstadt (11), part itself of a broader region named Darmstadt (DE 71), a NUTS 2 level region with the 13th highest level GDP per capita in Europe (Eurostat, 2013)

Kreisfreie Stadt Darmstadt, shown in the map below, is composed of nine 'Stadtteile' (boroughs): Arheilgen. Bessungen. Eberstadt, Kranichstein, Darmstadt-Mitte, Darmstadt-Nord, Darmstadt-Ost, Darmstadt-West, Wixhausen. Kreisfreie Stadt Darmstadt has a population of around 150 000 inhabitants, and Darmstadt Larger Urban Zone comes close to a half million inhabitants.

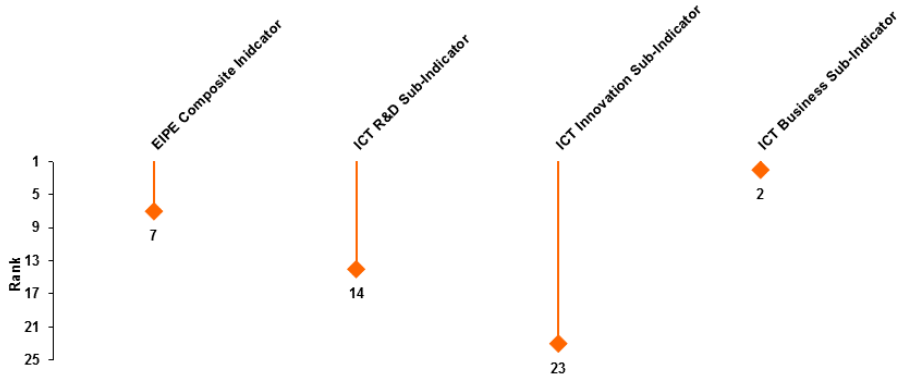
Henceforth, the report often uses the term "Darmstadt" to refer to **Kreisfreie Stadt Darmstadt**.

[37] Nomenclature of Territorial Units for Statistics (NUTS). For a list of the European statistical regions see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction. Source of the map: Wikipedia.

4.1 Kreisfreie Stadt Darmstadt in the EIPE ranking

Kreisfreie Stadt Darmstadt (DE711), henceforth Darmstadt, reached the 7th place among 1303 regions in Europe according to the EIPE composite indicator (Figure 14). It is surpassed by Kreisfreie Stadt Munchen, Inner London East, Paris, Stadtkreis Karlsruhe, Cambridgeshire CC and Stockholms lan (see **Figure 3**). **Figure 14** shows Darmstadt's position by individual sub-indicators. According to this information, Darmstadt comes 14th in R&D, 23rd in innovation and 2nd in business activity.

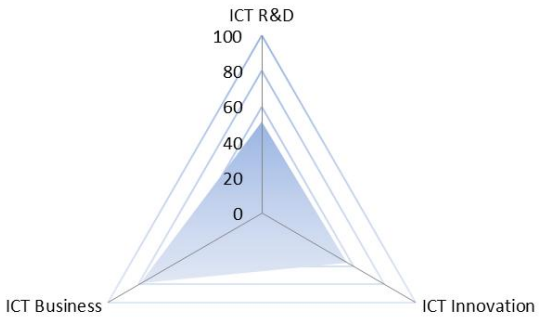
Figure 14: Darmstadt in the EIPE ranking by EIPE composite indicator, ICT R&D, Innovation and Business sub-indicators



Note: The graph shows the performance of Kreisfreie Stadt Darmstedt in the overall EIPE ranking and the ICT R&D, ICT Innovation and ICT Business ranking. The scale represents the rank in comparison with the remaining 1302 European Nuts 3 regions. For further methodological details, please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

Its relative performance in all three domains, i.e. ICT R&D, ICT Innovation and ICT Business, is depicted in **Figure 15**. This figure shows that Darmstadt, in comparison with the remaining 1,302 EU NUTS 3 regions, is particularly strong in ICT Business activities and less strong in ICT R&D and ICT innovation activities.

Figure 15: Performance of Darmstadt in ICT R&D, Innovation and Business



Note: The graph represents the performance of Darmstadt in the ICT R&D, ICT Innovation and ICT Business rankings. The scale represents normalized scores with maximum 100 and minimum 0. The rankings are based on the analysis of 1303 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

A more detailed picture of Darmstadt's rankings in each of the 42 indicators, i.e. the Darmstadt EIPE ID card, is presented in **Table 42**. In the following sections, information for each of these indicators

is given. Thus, a detailed picture of ICT activity in Darmstadt, fully based on the data collected during the study to construct the 42 indicators, is offered.

Table 42: Darmstadt EIPE ID card

Activity	Characteristic	Name of Indicator	Indicator ID	Rank
R&D	Agglomeration	Universities ranked in the QS University Ranking	AgRD 1	2
		Academic ranking of a Computer Science faculty	AgRD 2	35
		Employer ranking of a Computer Science faculty	AgRD 3	51
		Citations ranking of a Computer Science faculty	AgRD 4	55
		R&D expenditures by ICT firms	AgRD 5	8
		ICT FP7 funding to private organisations	AgRD 6	12
		ICT FP7 participations	AgRD 7	12
		ICT FP7 funding to SMEs	AgRD 8	12
		ICT FP7 participations by SMEs	AgRD 9	12
		Location of ICT R&D centres	AgRD 10	314
		Ownership of ICT R&D centres	AgRD 11	21
		Scientific publications in Computer Science	AgRD 12	3
	Internationalisation	Outward ICT R&D internationalisation	IntRD 1	21
		Inward ICT R&D internationalisation	IntRD 2	260
	Networking	Degree in ICT R&D network	NetRD 1	72
		Closeness centrality in ICT R&D network	NetRD 2	72
		Betweenness centrality in ICT R&D network	NetRD 3	62
		Eigenvector centrality in ICT R&D network	NetRD 4	75
Innovation	Agglomeration	Investment in intangibles by ICT firms	AgIn 1	13
		Venture Capital financing to ICT firms	AgIn 2	24
		ICT patents	AgIn 3	17
	Internationalisation	International co-inventions	IntIn 1	12
	Networking	Degree in ICT innovation network	NetIn 1	35
		Closeness centrality ICT innovation network	NetIn 2	48
		Betweenness centrality ICT innovation network	NetIn 3	54
		Eigenvector centrality ICT innovation network	NetIn 4	113
Business	Agglomeration	Location of ICT Scoreboard Headquarters	AgBuss 1	13
		Ownership of ICT Scoreboard affiliates	AgBuss 2	1
		Location of ICT Scoreboard affiliates	AgBuss 3	2
		Location of ICT firms	AgBuss 4	6
		ICT employment	AgBuss 5	18
		Growth in ICT employment	AgBuss 6	31
		Turnover by ICT firms	AgBuss 7	20
		Growth in turnover by ICT firms	AgBuss 8	10
		New business investments in the ICT sector	AgBuss 9	1
	Internationalisation	Outward ICT business internationalisation	IntBuss 1	17
		Inward ICT business internationalisation	IntBuss 2	5
	Networking	In-degree in ICT business network	NetBuss 1	28
		Out-degree in ICT business network	NetBuss 2	4
		Closeness centrality in ICT business network	NetBuss 3	13
		Betweenness centrality in ICT business network	NetBuss 4	22
		Eigenvector centrality in ICT business network	NetBuss 5	34

Note: The table reports the performance of Darmstadt in each out of the 42 indicators used in the EIPE ranking and grouped around three dimensions, i.e. ICT R&D, ICT Innovation and ICT Business. The scale represents the rank in the comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

4.2 ICT R&D

This section sheds light on Darmstadt's performance in ICT R&D activities by making use of the information collected in the EIPE project. This analysis follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. Detailed background information on the ranking of Darmstadt by the R&D indicators listed in this region's EIPE ID card can be found in **Table 42**. The next sections analyse ICT R&D activities in Darmstadt by looking at the following characteristics:

- ICT R&D Agglomeration (AgRD), i.e. performance of universities and research organisations; private and public ICT R&D expenditures and the location of ICT R&D centres (Section 0),
- ICT R&D Internationalisation (IntRD), i.e. the number of ICT R&D centres located outside Germany that are owned by companies with headquarters in Darmstadt (outward internationalisation) and the number of ICT R&D centres located in Darmstadt that are owned by foreign companies (inward internationalisation) (Section 0).
- ICT R&D Networking (NetRD), i.e. linkages formed by research organizations located in Darmstadt when they participate in joint ICT FP7 programmes with organizations located in other regions (Section 0).

4.2.1 ICT R&D Agglomeration (AgRD)

The analysis of ICT R&D Agglomeration in Darmstadt starts by providing a snapshot of the universities and the bibliometric output of organizations located in the region (see Table 43). This information is based on the QS World University Rankings (reference year 2008) and the Thomson Reuters Web of Knowledge (2000-2012). For the methodology of indicator construction, see Section 0.

Though Darmstadt only has one university (Technische Universität Darmstadt) that is included in the QS World Unitversity Ranking, this region ranks 2nd for universities. This is because the analysis takes into account the fact that the region has a small population in comparison with other European regions.

A closer look at the specific performance of the Computer Science faculty of the Technische Universität Darmstadt shows that, in comparison with faculties of this kind in other European regions, it ranks between 35th and 55th respectively for the indicators 'academic ranking' and 'employer and citations ranking'.

As regards the indicator "scientific publications in Computer Science", the research organisations based in Darmstadt produced over 656 (1% of EU total) between 2000 and 2012 (as registered by Thomson Reuters). Considering its share in the EU population, Darmstadt comes third in this indicator in the EU rankings. Obviously, the Technische Universität Darmstadt accounts for almost 100% of these publications.

Table 43: ICT R&D Agglomeration: Universities & bibliometrics

Indicator ID	Name of indicator	Rank	Darmstadt universities in QS university ranking	
AgRD 1	**Universities ranked in the QS University Ranking**	2	Technische Universität Darmstadt	
			The best performing Computer Science faculty of a Darmstadt university according to the …	
AgRD 2	**Academic ranking of a Computer Science faculty**	35	Technische Universität Darmstadt	
AgRD 3	**Employer ranking of a Computer Science faculty**	51	Technische Universität Darmstadt	
AgRD 4	**Citations ranking of a Computer Science faculty**	55	Technische Universität Darmstadt	
AgRD 12	**Scientific publications in Computer Science**	3	**Total number of publications**	**% in EU total**
			778	1%
			Research organizations with the highest number of publications, number of publications in brackets	
			Technische Universität Darmstadt (656)	

Regarding public ICT R&D expenditures, they are proxied here by ICT FP7 funding data attributed to research projects in which private and/or public organizations, based in Darmstadt participated in the time period between 2007 and 2011 (see **Table 44**).

Given its share in total EU population, Darmstadt ranks 12th in the EU as regards FP7 funding to organizations. Between 2007 and 2011, organizations based in Darmstadt received 30 Million Euro for FP7 projects. This represents 0.25% of the total EU ICT FP7 funding. The five organizations that received the highest amount of funding were: Technische Universität Darmstadt, Zentrum für Graphische Datenverarbeitung, an industry association, and three private companies, i.e. Siemens AG, Merck Chemicals and Software AG, the second largest second largest software vendor in Germany, after SAP.

Darmstadt also ranks 12th among the European regions (again taking into account its share of the total EU population) with respect to the number of participations in FP7 projects. Between 2007 and 2011, organizations based in Darmstadt participated in 75 FP7 projects. This represents 0.25% of all FP7 projects in this period. The organizations that participated in the highest number of FP7 projects were Technische Universität Darmstadt and the four private companies mentioned above. Altogether they participated in over 61% of all the projects granted to organizations based in Darmstadt.

Table 44: ICT R&D Agglomeration: FP7 funding and participation

Indicator ID	Name of indicator	Rank		
AgRD 6	FP7 funding	12	**Total amount of funding (in M of Euro)**	**% in EU total**
			30	0.25%
			Research organizations based in Darmstadt with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			1. TECHNISCHE UNIVERSITEIT DARMSTADT (15) 2. SIEMENS AG (2) 3. ZENTRUM FÜR GRAPHISCHE DATENVERARBEITUNG (2) 4. MERCK CHEMICALS LTD (1) 5. SOFTWARE AG (1)	
AgRD 7	FP7 participations	12	**Number of participations**	**% in EU total**
			75	0.25%
			Research organizations based in Darmstadt with the highest number of participations in FP7 projects, number of participations in brackets	
			1. TECHNISCHE UNIVERSITÄT DARMSTADT (31) 2. VSONIX GMBH (5) 3. ZENTRUM FÜR GRAPHISCHE DATENVERARBEITUNG EV (4) 4. MERCK CHEMICALS LTD (3) 5. SILTRONIC AG (3)	
AgRD 8	FP7 funding to SMEs	12	**Total amount of funding (in M of Euro)**	**% in EU total**
			7	0.31%
			SMEs based in Darmstadt with the highest amount of funding, amount per organization in brackets	
			1. ZENTRUM FÜR GRAPHISCHE DATENVERARBEITUNG EV (2.1) 2. VSONIX GMBH (1.1) 3. TRIVISIO PROTOTYPING GMBH (0.8) 4. GLOBIT - GLOBALE INFORMATIONSTECHNIK GMBH (0.7) 5. FLYING EYE MANAGEMENTBERATUNG FÜR MEDIENINVEST. (0.4)	
AgRD 9	FP7 participations by SMEs	12	**Number of participations**	**% in EU total**
			23	.32%
			SMEs based in Darmstadt with the highest number of participations in FP7 projects, number of participations in brackets	
			1. ZENTRUM FÜR GRAPHISCHE DATENVERARBEITUNG EV (4) 2. VSONIX GMBH (4) 3. TRIVISIO PROTOTYPING GMBH (2) 4. FLYING EYE MANAGEMENTBERATUNG FÜR MEDIENINVEST. (2) 5. GLOBIT - GLOBALE INFORMATIONSTECHNIK GMBH (2)	

Darmstadt, given its share of the total EU population, again ranks 12th among all the European regions for the amount of FP7 funding granted to SMEs. Between 2007 and 2011, SMEs based in

Darmstadt received 7 Million Euro for FP7 projects. This represents 0.31% of the total EU ICT FP7 funding to SMEs. A similar picture emerges when we look at the number of participations in FP7 projects by SMEs based in Darmstadt. Here, again, one can see that, given its share in the total EU population, Darmstadt ranks 12th among all the European regions. Darmstadt-based SMEs were involved in 23 FP7 projects, i.e. slightly above 0.31% of FP7 projects in which SMEs participated Europe-wide. Thus, taking into account the overall share of participations in FP7 funding by organizations based in Darmstadt, i.e. 0.25% in the EU total, SMEs based in this region show a rather high participation rate to the FP7 projects.

Information on average annual expenditures on R&D by ICT firms and on the location and ownership of ICT R&D centres is used to provide further details on ICT R&D agglomeration (see **Table 45**). Data on the average annual amount spent on R&D in the ICT sector, for the period 2005 – 2011, originate from the ORBIS database developed by Bureau Van Dijk. Data on the location and ownership of ICT R&D centres is for 2012 and stems from the Design Activity Tool developed by IHS iSuppli, an industry consultancy which specialises in observing the ICT sector.

Darmstadt, given its share of the total EU population, ranks 8th among the European regions with respect to average annual expenditure on R&D by ICT firms. In the period between 2005 and 2011, ICT firms based in Darmstadt spent on average 0.07 Million Euro annually on R&D. This represents 0.3% of the total EU R&D expenditures by ICT firms. ICT firms with the highest R&D budgets based in Darmstadt were, for example, Software AG, Prout AG and 10Tacle Studios AG.

Darmstadt has no R&D facilities owned by *major semiconductor influencers,* nor does it have companies that could themselves be considered to be *major semiconductor influencers* according to the IHS iSuppli definition. Hence, this region comes 314th and 21st in these two rankings, sharing these positions with other European regions where there are neither major semiconductor influencers nor their R&D facilities.

Table 45: ICT R&D Agglomeration: R&D expenditures and R&D centres

Indicator ID	Name of indicator	Rank		
AgRD 5	R&D expenditures by ICT firms	8	**Total amount of funding (in M of Euro)**	**% in EU total**
			0.07	0.3%
			R&D investors based in Darmstadt with the highest amount of R&D expenditures	
			1. SOFTWARE AG 2. PROUT AG 3. 10TACLE STUDIOS AG 4. MIS AG	
AgRD 10	Location of ICT R&D centres	314	**Number of R&D centres located in Darmstadt**	**% in EU total**
			n.a	n.a.
			Firms with the highest number of R&D centres located in Darmstadt	
			n.a.	
AgRD 11	Ownership of ICT R&D	21	**Number of R&D centres owned by firms based in Darmstadt**	**% in EU total**
			n.a.	n.a.
			Firms based in Darmstadt with the highest number of R&D centres owned worldwide	
			n.a.	

4.2.2 ICT R&D Internationalisation (IntRD)

The analysis of ICT R&D Internationalisation in Darmstadt is based on data on the location and ownership of R&D centres for 2012 provided by the Design Activity Tool (published by HIS iSuppli, an industry consultancy which specialises in the ICT sector). For the indicator construction methodology, see Section 0. The information on ICT R&D internationalisation in Darmstadt is presented in **Table 46**.

As already noted in the previous section (see **Table 45**), Darmstadt has neither major semiconductor influencers nor their R&D facilities. Hence, this region ranks 21st and 260th respectively in outward and inward ICT internationalisation, sharing these positions with other European regions which also do not have semiconductor influencer or their R&D facilities.

Table 46: Outward and inward R&D internationalisation

Indicator ID	Name of indicator	Rank	
InRD 1	Outward ICT R&D internationalisation	21	**Number of ICT R&D centres located outside of Germany that are owned by companies' headquarters located in Darmstadt**
			n.a.
			Top locations of R&D centres owned by firms from Darmstadt
			n.a.
InRD 2	Inward ICT R&D internationalisation	260	**Number of ICT R&D centres located in Darmstadt that are owned by foreign companies**
			n.a.
			Origins of companies with R&D centres located in Darmstadt
			n.a.

4.2.3 ICT R&D Networking (NetRD)

In order to construct an ICT R&D network and to assess the position of individual regions in it, we rely on data on participation in the ICT part of the FP7 programme. All NUTS3 regions where FP7 ICT R&D programme partners are located are identified as nodes of the network. Bilateral relationships (arcs of the network) between regions exist whenever an organisation from one region participates in a FP7 ICT R&D programme together with an organization from a different region.[38] This allows us to construct a set of network measures for each region and the analysis of these measures for Darmstadt is presented below.

Analysing the network of collaborations in the FP7 ICT R&D programme allows us to see Darmstadt's specific position in the EIPE ranking and better understand its high position and the role it plays in the European ICT landscape.

This analysis focuses on 3 successive steps:

[38] For more details on the methodology of constructing a network and its application to ICT R&D, see section 0.

- Darmstadt's position in the ICT R&D network, as observed from the collaborative links established by the organisations located in Darmstadt with organisations located in other European regions, and the characteristics of these links.
- The characteristics of Darmstadt ego network[39] formed by its first degree partners in the ICT R&D network.
- Darmstadt's top 20 partners in the ICT R&D network and the number of joint projects with each.

For the methodology for indicator construction, see Section 0.

Darmstadt's position in the ICT R&D network

Table 47, which presents Darmstadt's ranking in the ICT R&D network, confirms the rather central role Darmstadt plays in the ICT R&D network, but with the following nuances:

- Darmstadt comes 72nd out of 761 regions in the degree ranking. This indicator is based on the number of collaborations a given region maintains with other regions in the ICT R&D network in altogether 542 FP7 programmes that research organizations based in Darmstadt participated in between 2007 and 2012. Darmstadt is directly **connected with 197 regions** (26% of the all the regions) that participate in the ICT R&D network.
- Darmstadt also comes 72nd in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance from other nodes in the network. It shows that Darmstadt **is rather close** to the remaining 760 regions in the ICT R&D network.
- Darmstadt comes 62nd in the betweenness ranking, which reflects the position of a node as a hub in the network. Thus, to some extent, Darmstadt plays **an intermediary role** between other nodes of the ICT R&D network.
- Darmstadt comes 75th in the Eigenvector centrality ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT R&D network. Thus, despite being connected to **well-connected nodes**, a large share of Darmstadt's neighbours are small and medium-sized nodes placed in less central positions in the network.

Table 47: Ranks of Darmstadt in the ICT R&D network by network measures

Indicator ID	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	Degree in ICT R&D network	Closeness centrality in ICT R&D network	Betweenness centrality in ICT R&D network	Eigenvector centrality in ICT R&D network
Rank	72	72	62	75

The characteristics of Darmstadt's ego network

In order to get a deeper insight into the role of Darmstadt in the ICT R&D network, we have built its *ego network.* Darmstadt's ego network is a sub-network of the entire ICT R&D network, constructed

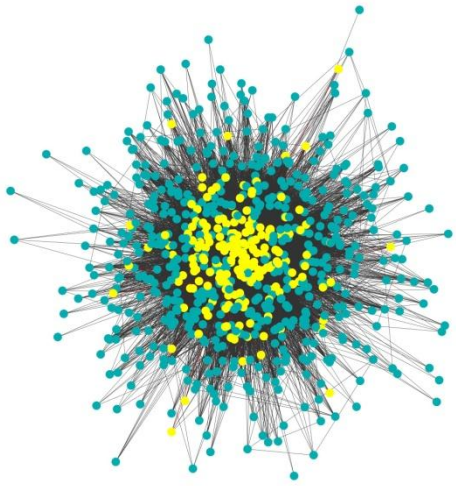
[39] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

by taking in account only Darmstadt's first degree partners (or alters), i.e. nodes directly connected with Darmstadt and the links among them.[40]

The characteristics of this ego network are then compared with those of the full ICT R&D network to see whether there are some structural differences between the full network and the ego network of the selected node, here Darmstadt. This way, we can understand better Darmstadt's neighbourhood in the ICT R&D network and, by casting some light on the attributes of its neighbours, to see how well it is embedded in the ICT R&D network.

An illustration of the full ICT R&D network (darker nodes) including the sub-network formed by Darmstadt's first degree partners (yellow nodes) is given in **Figure 16**. **Table 48** summarises the main measures of the Darmstadt ego network and compares it to the full ICT R&D network.

Figure 16: The ICT R&D network and the ego network of Darmstadt



Note: The graph represents the full ICT R&D network together with the ego network formed by Darmstadt's first degree partners represented by yellow nodes.

According to **Table 48**, Darmstadt's ego network includes 196 individual regions connected directly to Darmstadt, i.e. 26% of the regions in the full ICT R&D network. Altogether these regions form nearly over 9,000 linkages, i.e. 33% of the linkages in the entire network. Thus, the fact that only 26% of the regions in the full network account for 33% of all connections indicates that Darmstadt's neighbours are far better connected than an average node.

This is also confirmed by the density of the Darmstadt's ego network, which shows how well the network is connected. Darmstadt's ego network shows a **density** (i.e. a ratio of the actual number of links to the number of possible links) of 0.479, as compared to 0.095 for the full ICT R&D network. Thus, its ego network is significantly denser than the full ICT R&D network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. The score for Darmstadt's ego network is 0.786 - slightly higher than that of the full ICT R&D network. This indicates that the regions in Darmstadt's ego network are more clustered than the regions in the full ICT R&D network. In other words, due to the high value of the clustering coefficient observed in the Darmstadt's ego network, also here regions form tightly connected groups.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in

[40] Ego networks are also known as the neighbourhood networks or first degree neighbourhoods of ego Everett, M. & Borgatti, S. 2005. 'Ego network betweenness.' *Social Networks,* 27:1, 31-38.

the network. Darmstadt's ego network scores 0.527, whereas as the full ICT R&D network scores 0.6. Thus, because the variation in the nodes' centrality level in the ego network is significantly lower than in the full network, there is a smaller level of inequality between the nodes in Darmstadt's ego network than between the nodes in the full network. This might indicate that the network is largely populated by small and equal nodes, which are connected with the rest of the network through few hubs.

The **distance**[41] between any two nodes in Darmstadt's ego network, measured by the average path length, is 1.5, as compared to nearly 2 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT R&D network.

The **average number of direct neighbours** of the regions in the Darmstadt's ego network is 93, i.e. nearly 30% more than it is in the full ICT R&D network, where an average node has only 72 partners. Thus, Darmstadt's ego network is denser than the full network.

Table 48: Characteristics of Darmstadt's network vs. full ICT R&D network

Network-Level Measure	Full ICT R&D network	Darmstadt's ego network
Node Count	761	197
Link Count	27,490	9,242
Density	0.095	0.479
Clustering Coefficient	0.755	0.786
Network centralization	0.638	0.527
Average path length	1.980	1.521
Average number of neighbours	72	93

Darmstadt's top partners in the ICT R&D network

Table 49 gives the list of Darmstadt's top 20 partners in the ICT R&D network and the number of joint projects carried out with each. In addition, the rankings for each partner in the four network measures are given.

Of the 197 partners with which Darmstadt maintains direct connections in the ICT R&D network, relationships with the top **20 account for over 43%** of all the projects in which organisations located in Darmstadt were involved. This provides evidence for the existence of strong agglomeration forces in the shaping of the ICT R&D landscape.

Regarding the network characteristics of Darmstadt's top 20 partners, the first four collaborations are conducted with regions which play very strong and central roles in the network. For example, Darmstadt's main partners in terms of the number of joint projects are Paris and Munchen, the key nodes in the ICT R&D network according to the network measures reported in **Table 49**. The next two partners, e.g. Madrid and Attiki, are similarly important nodes in the network.

However, the rest of the list is not organized by the size of the node. For example, Wien – number 5 on Darmstadt's list of top 20 partners – comes 7th in terms of total degree, i.e. number of connections with other nodes in the network. Also the presence of such regions as Guipuzcoa and South-East Ireland shows that Darmstadt does not maintain strong connections with the top players

[41] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

in the network, but instead establishes relationships according to specific technological complementarities.

Table 49: Top 20 partners of Darmstadt in the ICT R&D network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint projects**	**Share in total**	**Degree in ICT R&D network**	**Closeness centrality in ICT R&D network**	**Betweennes s centrality in ICT R&D network**	**Eigenvector centrality in ICT R&D network**
1	FR101	Paris	31	5.7%	2	2	2	2
2	DE212	Kreisfreie Stadt Munchen	26	4.8%	1	1	1	1
3	ES300	Madrid	18	3.3%	3	3	4	3
4	GR300	Attiki	18	3.3%	4	4	6	4
5	AT130	Wien	15	2.8%	11	11	11	10
6	ITE43	Roma	14	2.6%	7	7	3	7
7	FI181	Uusimaa	12	2.2%	9	9	9	9
8	DE122	Stadtkreis Karlsruhe	10	1.8%	12	12	15	15
9	ITC45	Milano	10	1.8%	6	6	5	6
10	UKI12	Inner London East	10	1.8%	4	4	7	5
11	FR105	Hauts-de-Seine	9	1.7%	20	20	25	16
12	ITC11	Torino	9	1.7%	16	16	16	18
13	DEA23	Koln, Kreisfreie Stadt	8	1.5%	39	39	43	48
14	NL326	Groot-Amsterdam	8	1.5%	21	21	21	25
15	NL414	Zuidoost-Noord-Brabant	8	1.5%	17	17	22	17
16	BE242	Arr. Leuven	7	1.3%	13	13	13	13
17	HU101	Budapest	7	1.3%	19	19	19	20
18	IE024	South-East (IRL)	6	1.1%	111	112	157	78
19	ES212	Guipuzcoa	5	0.9%	52	52	46	57
20	ES511	Barcelona	5	0.9%	8	8	8	8
Total Top 20			**236**	**43.5%**				
Total			**542**	**100%**				

4.3 ICT innovation

This section sheds light on Darmstadt's performance in ICT innovation activities. It makes use of the information collected in the EIPE project and follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. **Table 42** - Darmstadt EIPE ID card – gives detailed background information on this region's ranking by ICT innovation indicators. ICT Innovation activities in Darmstadt are analysed by looking at the following characteristics:

- ICT Innovation Agglomeration (AgIn), i.e. investment in intangibles by ICT firms, venture capital financing to ICT firms and ICT patents,
- ICT Innovation Internationalisation (IntIn), i.e. the number of ICT inventions developed by inventors located in Darmstadt and outside of Germany,
- ICT Innovation Networking (NetIn) i.e. the place of Darmstadt in the ICT innovation network formed by co-inventions jointly developed by inventors located in regions around the world.

4.3.1 ICT Innovation Agglomeration (AgIn)

The analysis of the ICT Innovation Agglomeration in Darmstadt starts with providing information on the amount of investment in intangibles by ICT firms, venture capital funding to ICT firms and the number of ICT patents (see **Table 50**). This data comes from the company-level database ORBIS by Bureau Van Dijk (reference years from 2005 to 2012), Venture Source by Dow Jones (reference years from 2000 to 2012) and REGPAT by OECD-EPO (reference years from 2000 to 2012) respectively. For the methodology for indicator construction, see Section 0.

Darmstadt, given its share in the total EU population, ranks 13th among the European regions with respect to average annual investment by ICT firms in intangibles,. According to the company-level database ORBIS by Bureau Van Dijk, in the period 2005 - 2011, ICT firms based in Darmstadt spent on average 0.6 Million Euro annually on intangibles. This represents 0.15% of the total EU investment in intangibles by ICT firms. The ICT firms based in Darmstadt which invested most in intangibles were, for example, Software AG, Prout AG and 10TACLE STUDIOS AG.

Regarding the number of venture capital deals made with ICT firms, Darmstadt ranks 24th among all the EU regions. Between 2000 and 2012, over 52 VC deals were made with ICT firms based in Darmstadt. Funded companies include, among others, Fludicon GmbH, a developer of intelligent and flexible system solutions based on electrorheological technology for industry and the automotive sector; ISRA Vision Systems, a developer and provider of user-specific software for sophisticated, intelligent Machine Vision systems; and Vrcom, a spin-off of the graphical data processing department of the German research group Fraunhofer Institute for Computer Graphics in Darmstadt that develops and deploys field-tested, applications-oriented solutions in the area of virtual reality.

ICT innovation output is measured here by the number of ICT patents. Organisations based in Darmstadt produced 319 (0.26% of EU total) patented ICT inventions between 2000 and 2012. This figure and Darmstadt's share in the EU population put the region in 17th place in this ranking.

Table 50: ICT Innovation agglomeration in Darmstadt

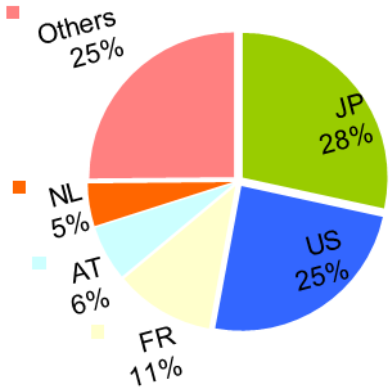
Indicator ID	Name of indicator	Rank		
AgIn 1	Investment in intangibles by ICT firms	13	**Total amount of (in M of Euro)**	**% in EU total**
			0.63	0.15%
			Top investors in intangibles by firms based in Darmstadt	
			1. SOFTWARE AG 2. PROUT AG 3. 10TACLE STUDIOS AG 4. MIS AG	
AgIn 2	Venture Capital financing to ICT firms	24	**Number of VC financial deals to firms based in Darmstadt**	**% in EU total**
			52	0.2%
			Organizations with the highest amount of VC funding	
			1. Fludicon GmbH 2. ISRA Vision Systems 3. VRCom GmbH 4. 10Tacle Studios 5. IPAG - Innovative Processing	
AgIn 3	ICT patents	17	**Total number of ICT patents**	**% in EU total**
			319	0.26%

4.3.2 ICT Innovation Internationalisation (IntIn)

The analysis of ICT Innovation Internationalisation in Darmstadt is based on the data on ICT international co-inventions, i.e. the number of patents with an inventor residing in Darmstadt and at least one inventor residing outside of Germany. The data originates from REGPAT (source: OECD-EPO) and cover 2000 to 2012. For the methodology for indicator construction, see Section 0.

According to the information presented in **Table 51**, of the total 319 ICT inventions that included Darmstadt-based inventors, 122 were an output of international collaborations involving partners from outside Germany. This gives Darmstadt a 12th place in the current ranking. The main external partners in ICT co-inventing activity in Kareisfreie Stadt Darmstadt are from Japan, the US, France, Austria and the Netherlands.

Table 51: ICT innovation internationalisation of Darmstadt

Indicator ID	Name of indicator	Rank	
IntIn 1	International co-inventions	12	**Number of international ICT co-inventions**
			122
			Top countries by the number of co-inventions between inventors located in Darmstadt and ...
			

4.3.3 ICT Innovation Networking (NetIn)

In order to construct an ICT innovation network and to assess the position of individual regions in it, we rely on the network analysis of the locations of inventors residing in different regions and jointly developing ICT inventions for which a patent application has been introduced. The relationship between two different locations can be described as the total sum of co-inventions developed by inventors residing in these two regions (Guellec and Van Pottelsberghe de la Potterie 2001).

We identify all regions where inventors are located as nodes of the network. Bilateral relationships (arcs of the network) exist between regions whenever an inventor from one region co-developed an invention with an inventor based in a different region.[42] These definitions allow us to construct a set of network measures for each region: the analysis of those measures in the case of Darmstadt is presented below.

Analysing this network of inventor collaborations in technology development allows us to observe the specific position of Darmstadt in the ICT innovation network, as compared to other European

[42] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0.

regions. It also enables us to better understand its position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Darmstadt's position in the ICT innovation network, as observed from the collaborative links established by inventors located in Darmstadt with inventors located in other regions around the world, and the characteristics of these links,
- The characteristics of the ICT innovation ego network[43] of first degree partners of Darmstadt,
- Darmstadt's top 20 partners in the ICT innovation network and the number of inventions patented jointly with each.

For the methodology of indicator construction, see Section 0.

Darmstadt's position in the ICT innovation network

Table 52, which presents Darmstadt's ranking in the ICT innovation network, shows that Darmstadt plays a rather central role in the ICT innovation network, but with the following nuances:

- Darmstadt comes 72nd out of 1,189 European regions (out of 3,656 in total worldwide) in the ICT innovation network by the degree indicator. This indicator is based on the number of collaborations a given region maintains with other regions in the ICT innovation network with altogether 3646 regions worldwide through joint co-inventions in the period between 2000 and 2009. Darmstadt is directly **connected with 318 regions** (9% of all the regions) that participate in the ICT innovation network.
- Darmstadt also comes 72nd in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Darmstadt is shown to be **rather close** to the remaining regions forming the ICT innovation network.
- Darmstadt comes 62nd in the betweenness ranking, reflecting its position as a node which is a hub in the network. It is worth noting that this is considerably higher than the degree or closeness ranking, which tells us that Darmstadt plays **an important intermediary role** between other nodes in the ICT innovation network.
- Darmstadt comes 75th in the Eigenvector centrality ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT innovation network. Thus, it can be concluded that a large share of Darmstadt's neighbours are similar or smaller in terms of the number of their connections. Hence, these are small and medium-sized nodes placed in less central positions in the network.

Table 52: Darmstadt's rankings in the ICT innovation network by network measures

Indicator ID	NetIn 1	NetIn 2	NetIn 3	NetIn 4
Indicator Name	Degree in ICT innovation network	Closeness centrality in ICT innovation network	Betweenness centrality in ICT innovation network	Eigenvector centrality in ICT innovation network
Rank	72	72	62	75

[43] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

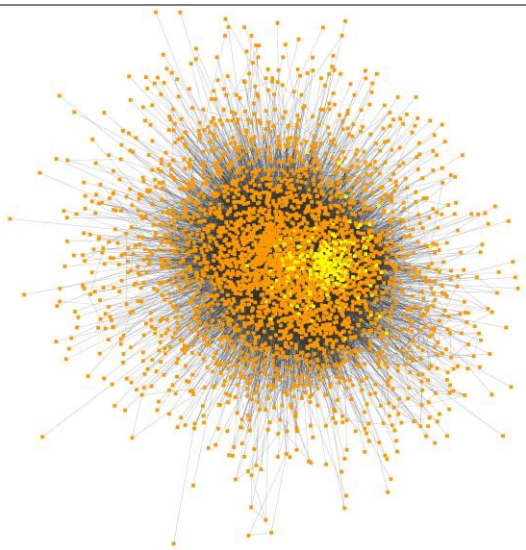
The characteristics of Darmstadt's ego network

In order to get a deeper insight into the role of Darmstadt in the ICT innovation network, we have constructed its ego network, i.e. a network consisting of Darmstadt (ego), the actors it is connected to (alters) and all the links between these alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Darmstadt's ego network is constructed by taking into account only Darmstadt's first degree partners, i.e. nodes directly connected with Darmstadt and the links between them.

The characteristics of this ego network are compared with those of the full ICT innovation network to see whether there are some structural differences between the full network and the one of the selected node, Darmstadt with its direct partners. This comparison will help us to understand better Darmstadt's position in the ICT innovation network. In addition, by casting some light on its neighbours' attributes, it will allow us to see how well the region's neighbourhood network is embedded in the ICT innovation network.

An illustration of the full ICT innovation network and its sub-network formed by Darmstadt's first degree partners (yellow nodes) is given in Figure 17. Table 53 summarises the main measures of the Darmstadt ego network and compares it to the full ICT innovation network.

Figure 17: The ICT innovation network and the ego network of Darmstadt



Note: The graph represents the full ICT innovation network together with the ego network formed by Darmstadt's first degree partners represented by yellow nodes.

According to Table 53, Darmstadt's ego network includes 318 individual regions connected directly to Darmstadt, i.e. 9% of the regions present in the full ICT innovation network. Altogether these regions form nearly 12,677 linkages, i.e. 13% of the linkages in the entire network. Thus, the fact that only 9% of the full network regions account for 13% of its total connections indicates that Darmstadt's neighbours are far better connected than average nodes.

This is also confirmed by the density measure, i.e. a ratio of the actual number of links to the number of possible links, which shows how well the network is connected. Darmstadt's ego network has a **density** of 0.25, as compared to 0.014 for the full ICT innovation network. Thus, the ego network is significantly denser than that of the full ICT innovation network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. The Darmstadt ego network's score is 0.583, which is higher than that of the full ICT innovation network. This indicates that the regions present in Darmstadt's ego

network are clustered into more tightly connected groups as compared to the other regions in the full ICT innovation network.

The **network centralization** level of a network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. For the Darmstadt's ego network, it scores 0.753, as compared to 0.3 for the full ICT innovation network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network in terms of their position in the network. This indicates that there are few nodes with very central positions in the Darmstadt's network and numerous nodes that play less central roles.

The **distance**[44] between any two nodes in the Darmstadt's ego network, measured by the average path length, is 1.7, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT innovation network.

The **average number of direct neighbours** of the regions included in the Darmstadt's ego network is 90, i.e. over 70% more than in the in the full ICT innovation network, where an average node has only 52 partners. This confirms that the regions in the Darmstadt's ego network show a higher density of connections than the average in the full network.

Table 53: Characteristics of Darmstadt's ego network vs. full ICT innovation network

Network-Level Measure	Full ICT innovation network	Darmstadt's ego network
Node Count	3,646	318
Link Count	94,689	12,677
Density	0.014	0.252
Clustering Coefficient	0.499	0.583
Network centralization	0.320	0.753
Average path length	2.676	1.748
Average number of neighbours	51.941	89.730

Top 20 partners of Darmstadt in the ICT innovation network

Table 54 lists Darmstadt's top 20 partners in the ICT innovation network, showing the number of joint patents with each. In addition, the four network measures are ranked for each partner. Because the total list of partners also includes non-EU regions, the ranks of the neighbours are given for the whole network, i.e. including non-EU regions. Hence, this way, the ranks presented here are not comparable with the ranking of the EU regions.

Of the 315 partners with which Darmstadt maintains direct connections in the ICT innovation network, the relationships with **the top 20 partners account for nearly 70%** of all co-patents between innovators based in Darmstadt and other regions. This provides evidence for the existence of strong agglomeration forces in the shaping of the ICT Innovation landscape.

It can be seen that that most of the inventors from the top 20 partners who work with Darmstadt' inventors are located in regions near Darmstadt or in Germany. For example, the major partners in

[44] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

terms of the number of joint patents include Darmstadt-Dieburg (DE716), Offenbach, Landkreis (DE716) and Miltenberg (DE269). Among the top 20 partners of Darmstadt in the ICT innovation network, only one is from outside of Germany, i.e. Kanagawa (JPC14). Thus, unlike in the ICT R&D network (see Section 0), the intensity of the interaction is less related to the partner's position in the network and more to its geographical proximity.

Table 54: Darmstadt's top 20 partners in the ICT innovation network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint patents**	**Share in total**	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweennes s centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
1	DE716	Darmstadt-Dieburg	40.9	26.7%	65	163	129	452
2	DE71C	Offenbach, Landkreis	7.9	5.2%	188	474	360	547
3	DE269	Miltenberg	6.5	4.2%	697	1106	1306	1472
4	DE712	Frankfurt am Main	6.4	4.2%	66	139	126	483
5	DE212	München, Kreisfreie	4.9	3.2%	8	18	8	627
6	DE715	Bergstraße	4.8	3.1%	128	344	276	512
7	DE71A	Main-Taunus-Kreis	4.3	2.8%	106	218	244	451
8	DE300	Berlin	3.8	2.5%	9	26	11	337
9	DE718	Hochtaunuskreis	3.1	2.0%	147	259	259	530
10	DE717	Groß-Gerau	2.8	1.8%	330	788	750	687
11	DE21H	München, Landkreis	2.8	1.8%	11	34	25	590
12	DE128	Rhein-Neckar-Kreis	2.7	1.8%	37	100	63	1109
13	DE71D	Rheingau-Taunus-Kreis	2.2	1.4%	253	486	368	615
14	DE21L	Starnberg	2.2	1.4%	114	206	177	820
15	DE719	Main-Kinzig-Kreis	2.0	1.3%	144	337	340	463
16	DE21N	Weilheim-Schongau	1.9	1.2%	160	308	352	782
17	DE71E	Wetteraukreis	1.9	1.2%	313	649	613	609
18	DE71B	Odenwaldkreis	1.9	1.2%	588	814	929	928
19	JPC14	Kanagawa	1.8	1.2%	59	60	77	253
20	DE123	Karlsruhe, Landkreis	1.4	0.9%	106	256	196	1314
Total Top 20			**106.3**	**69.3%**				
Total nr of joint patents			**153.4**	**100%**				

4.4 ICT Business

This section sheds light on Darmstadt's performance in ICT business activities by making use of the information collected in the EIPE project. This analysis follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. Detailed background information on the region's rankings for the ICT business indicators is presented in **Table 42** (Kreiesfreie Stadt Darmstadt's EIPE ID card). ICT business activities are analysed by looking at the following characteristics:

- ICT Business Agglomeration (AgBuss), i.e. location of ICT Scoreboard companies and their affiliates, location of ICT firms, employment and turnover of ICT firms and new investments in the ICT sector (Section 0),
- ICT Business Internationalisation (IntBuss), i.e. the number of affiliates located outside Germany that are owned by ICT Scoreboard companies located in Darmstadt (outward internationalisation) and the number of affiliates located in Darmstadt that are owned by foreign ICT Scoreboard companies (inward internationalisation) (Section 0),

- ICT Business Networking (NetBuss), i.e. the position of Darmstadt in a network formed through linkages between regions around the world based on the location and ownership of ICT Scoreboard affiliates (Section 0).

4.4.1 ICT Business Agglomeration (AgBuss)

The analysis of ICT Business Agglomeration in Darmstadt starts with the key details on the actors based in Darmstadt (**Table 55**), their economic performance (**Table 56**) and ends with an overview of new investments in ICT in Darmstadt (**Table 57**).

This information is based on the company-level information provided by ORBIS by Bureau Van Dijk (reference years from 2005 to 2012)[45] and data collected in the European Investment Monitor by Ernst&Young for the period 1997-2011. For the methodology for indicator construction, see Section 0.

Kreiesfreie Stadt Darmstadt, given its share of the total EU population, ranks 13th among the EU regions for the number of ICT Scoreboard company headquarters it hosts. This is due to the presence of one firm that is on the list of the world's top 637 ICT R&D investors, i.e. Software A.G. This enterprise software company is the second largest software vendor in Germany, the fourth in Europe and among the top 25 globally. Software A.G. owns over 290 (3% of the EU total) affiliates located worldwide. Bearing in mind Darmstadt's share in the total EU population, the number of affiliates of that one firm gives the region the 1st position in the ranking.

With respect to the affiliates of the 637 ICT Scoreboard Headquarters, 79 of them are in Darmstadt. In other words, 1% of business affiliates belonging to any ICT Scoreboard Headquarter and based in the EU, is in Darmstadt. This puts Darmstadt 2nd in this ranking. Considering the location of ICT firms in Darmstadt, according to the ORBIS company-level database by Bureau Van Dijk, there are 4 ICT businesses (0.32% of EU total). This puts Darmstadt, given its size, 6th in this ranking.[46]

Table 55: ICT Business Agglomeration in Darmstadt

Indicator ID	Name of indicator	Rank		
AgBuss 1	Location of ICT Scoreboard Headquarters	13	**Number of ICT Scoreboard Headquarters located in Darmstadt**	**% in EU total**
			1	0.5%
			ICT Scoreboard Headquarters located in Darmstadt	
			1. Software AG	
AgBuss 2	Ownership of ICT Scoreboard affiliates	1	**Number of ICT Scoreboard affiliates owned worldwide by ICT Scoreboard Headquarters located in Darmstadt**	**% in EU total**
			294	3%
AgBuss 3	Location of ICT Scoreboard affiliates	2	**Number of ICT Scoreboard affiliates located in Darmstadt**	**% in EU total**
			79	1%
AgBuss 4	Location of ICT firms	6	**Number of ICT firms located in Darmstadt**	**% in EU total**
			4	0.32%

[45] The information available about business actors that is used here is the following: Location of ICT Scoreboard Headquarters, number of affiliates owned worldwide by ICT Scoreboard Headquarters based in the observed region, number of ICT Scoreboard affiliates located in the observed region and belonging to any of the ICT Scoreboard Headquarter and, finally, number of ICT firms located in the region.

[46] In order to avoid double-counting, separate searches were run using a filter on consolidation code. In the analysis, companies with consolidated accounts only were selected.

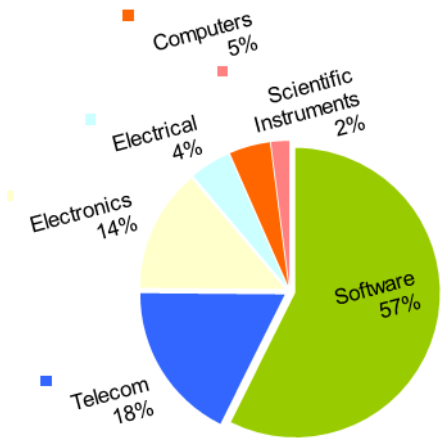
The above mentioned 4 ICT businesses based in Darmstadt provide over 0.18% of total EU employment and generate 0.12% of total EU turnover of the considered ICT firms (see Table 56). Bearing in mind Darmstadt's share in the total EU population, this puts the region 18th in employment and 20th for turnover. Taking into account business dynamics, 10% increase of employment and 20% increase of turnover between 2005 and 2012 gives Darmstadt 31st and 10th place among all the EU Nuts 3 regions.

Table 56: ICT Business Agglomeration in Darmstadt, cont.

Indicator ID	AgBuss 5	AgBuss 6	AgBuss 7	AgBuss 8
Indicator Name	ICT employment	Growth in ICT employment	Turnover by ICT firms	Growth in turnover by ICT firms
Rank	18	31	20	10
% in EU total / %	0.18%	10%	0.12%	20%

According to the information provided by the European Investment Monitor, between 1997 and 2011, there were nearly 200 new investments in Darmstadt by companies from the ICT sector (see Table 57). This constitutes 2% of all investments considered in the entire EU. Given the share of Darmstadt's population in the total EU population, it comes 1st in this ranking. A large share of these investments was in software (57%), electronics (18%) and telecommunications (14%).

Table 57: ICT Business Agglomeration in Darmstadt, cont.

Indicator ID	Name of indicator	Rank		
AgBuss 9	New business investments in the ICT sector	1	Number of new investments in the ICT sector in Darmstadt	% in EU total
			197	2%
			Distribution of new investments by activity type	
				

4.4.2 ICT Business Internationalisation (IntBuss)

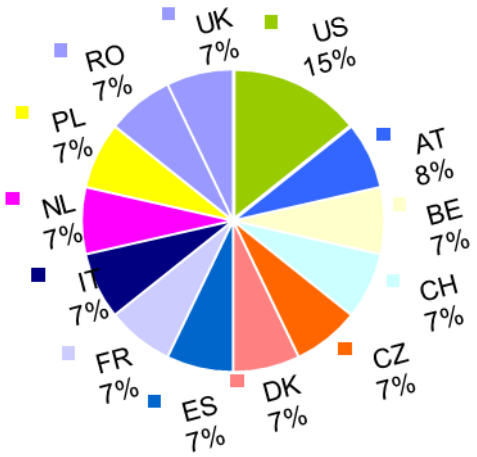
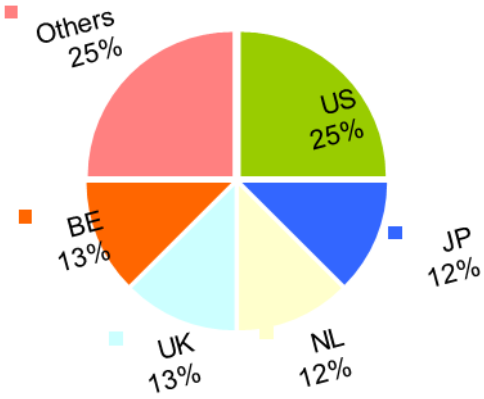
The analysis of ICT Business Internationalisation is based on the data on the location and ownership of affiliates by 637 ICT Scoreboard Headquarters and refers to 2008. This data comes from the company-level information provided by ORBIS by Bureau Van Dijk. Depending on the perspective, two types of internationalisation are considered, i.e. outward internationalisation measured by the number of affiliates located outside of Germany that are owned by ICT Scoreboard companies located in Darmstadt and inward internationalisation measured by the number of affiliates located

in Darmstadt that are owned by foreign ICT Scoreboard companies. For the methodology for indicator construction, see Section 0.

Darmstadt ranks 17th in ICT business internationalisation (see **Table 58**). This is due to the fact that Software A.G, the ICT Scoreboard Headquarter based in Darmstadt, owns altogether 16 affiliates (out of 294) outside Germany. Their major foreign business activity locations include the US and other European countries.

In terms of inward ICT business internationalisation, Darmstadt ranks 5th. According to the information provided in **Table 58**, 22 out of 79 affiliates located in Darmstadt which belong to ICT Scoreboard Headquarters are foreign owned. 25% of all foreign affiliates belong to ICT Scoreboard Headquarters based in the US. Other major owners are based in Japan, the Netherlands, the UK and Belgium.

Table 58: Outward and inward ICT business internationalisation

Indicator ID	Name of indicator	Rank	
InBuss 1	Outward ICT business internationalisation	17	**Number of affiliates located outside of Germany that are owned by ICT Scoreboard Headquarters located in Darmstadt**
			16
			Top foreign locations of affiliates owned by ICT Scoreboard Headquarters located in Darmstadt
			
InBuss 2	Inward ICT business internationalisation	5	**Number of affiliates located in Darmstadt that are owned by ICT Scoreboard Headquarters located abroad**
			22
			Origins of ICT Scoreboard Headquarters with affiliates located in Darmstadt
			

4.4.3 ICT Business Networking (NetBuss)

In order to construct an ICT business network and to assess the position of individual regions in it, we rely on the network analysis of the locations of ICT Scoreboard companies and their affiliates. This is done by linking a region where an ICT Scoreboard company is based with a region where it has at least one of its affiliates. Thus, we identify regions as nodes of the network where either an ICT Scoreboard company or affiliate is located. Bilateral relationships (arcs of the network) exist

between regions whenever an ICT Scoreboard company owns an affiliate in a different region.[47] This way we illustrate the destination of business expansion of ICT Scoreboard companies and the location of ICT business activities.[48] This allows us to construct a set of network measures for each region: the analysis of these measures in the case of Darmstadt is presented below.

Analysing this network of ICT business activity allows us to observe the specific position of Darmstadt in it. It also help us to better understand the region's position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Darmstadt's position in the ICT business network, as observed from the links established by the location and ownership of ICT Scoreboard affiliates,
- The characteristics of the ICT innovation ego network[49] of first degree partners of Darmstadt,
- The list of the Top 20 partners of Darmstadt in the ICT business network by the total number of outgoing (an affiliate located in Darmstadt and owned by an ICT Scoreboard company from a different region) and incoming connections (an affiliate owned by an ICT Scoreboard company located in Darmstadt and located in a different region).

For the methodology for indicator construction, see Section 0.

Darmstadt's position in the ICT business network

According to **Table 59**, which presents the ranking of Darmstadt in the ICT business network, the results show that Darmstadt is among the most central nodes in the ICT business network. In particular:

- Darmstadt comes 28th out of 485 European regions in the **in-degree** ranking in the ICT business network. This indicator is based on the number of affiliates located in Darmstadt that belong to any of the ICT Scoreboard companies headquartered outside of Darmstadt in 2008. In this ranking, Darmstadt is surpassed by Stadtkreis Karlsruhe, Koln, Kreisfreie Stadt and Essonne and followed by Kobenhavns omegn, Yvelines and Berkshire.
- Darmstadt comes 4th out of 243 European regions in the **out-degree** ranking in the ICT business network. This indicator is based on the number of regions in which ICT Scoreboard companies headquartered in Darmstadt have their business affiliates in year 2008. In this ranking, Darmstadt is surpassed only by Groot-Amsterdam, Munchen Kreisfreie Stadt and Paris.
- Darmstadt comes 22nd in the **closeness centrality** ranking for the European regions. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Darmstadt is shown to be a region that is **close to the other regions** of the ICT

[47] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0. For a full description of the methodology of network analysis and indicators applied, see the EIPE methodology report De Prato, G. & Nepelski, D. 2013a. 'Identifying European ICT Poles of Excellence. The Methodology.' *JRC Scientific and Policy Reports*. Seville: JRC-IPTS.

[48] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's new investment and headquarter is located in the same region.

[49] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

business network and is surpassed by regions such as Dublin, Yvelines and Hallands lan, and followed by Arr. Leuven, Skane lan and Madrid.

- Darmstadt comes 13th in the **betweenness ranking**, which reflects the position of a node as a hub in the network. Darmstadt has a very strong **intermediary role** between other nodes of the ICT business network, as compared to the other European regions. It is surpassed only by Milano, Stockholms lan and Stuttgart, Stadtkreis, and followed by Hochtaunuskreis, Hamburg and Wien.
- Darmstadt comes 34th in the **Eigenvector centrality** ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT business network. This way, one can say that Darmstadt is **connected with well-connected nodes**. However, a lower value of this score than the other centrality indices might indicate that many of the nodes with which Darmstadt is connected are less central than Darmstadt itself. In this ranking, Darmstadt is surpassed by regions such as: Arr. Halle-Vilvoorde, Rhein-Kreis Neuss and Hochtaunuskreis, and followed by Wien, Krefeld, Kreisfreie Stadt and Offenbach, Landkreis.

Table 59: Darmstadt's ranks in the ICT business network by network measures

Indicator ID	NetRD 1	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	In-degree in ICT business network	Out-degree in ICT business network	Closeness centrality in ICT business network	Betweenness centrality in ICT business network	Eigenvector centrality in ICT business network
Rank	28	4	22	13	34

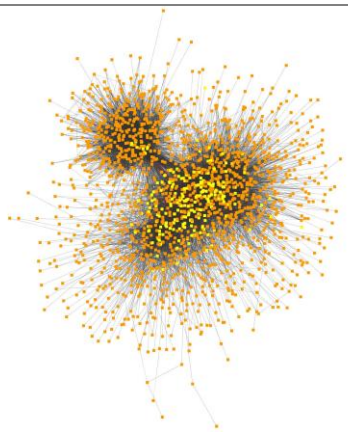
The characteristics of Darmstadt's ego network

In order to get a deeper insight into the role of Darmstadt in the ICT business network, we have constructed Darmstadt's ego network, i.e. a network consisting of Darmstadt (ego) together with the actors it is connected to (alters) and all the links among those alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Darmstadt's ego network is a sub-network of the ICT business network and is constructed by taking in account only Darmstadt's first degree partners, i.e. nodes directly connected with Darmstadt and the links between them.

The characteristics of this ego network are compared with those of the full ICT business network to see whether there are structural differences between the full network and that of the selected node, Darmstadt, and its direct partners. This way, we can understand better Darmstadt's neighbourhood in the ICT business network and, by casting some light on the attributes of its neighbours, see how well it is embedded in the ICT business network.

An illustration of the full ICT business network and its sub-network formed by Darmstadt's first degree partners (yellow nodes) is given in **Figure 18**. **Table 60** summarises the main measures of the Darmstadt ego network and compares this network to the full ICT business network.

Figure 18: The ICT business network and Darmstadt's ego network of



Note: The graph represents the full ICT business network together with the ego network formed by Darmstadt's first degree partners represented by yellow nodes.

According to **Table 60**, Darmstadt's ego network includes 135 individual regions connected directly to Darmstadt, i.e. 7% of the regions in the full ICT business network. Altogether these regions form over 1,100 linkages, i.e. around 6% of the linkages in the entire network. Thus, the fact that the share of nodes is higher than the share of all connections indicates that Darmstadt's neighbours are less connected with the remaining nodes than an average node.

The density measure, i.e. a ratio of the actual number of links to the number of possible links, shows how well the network is connected. Darmstadt's ego network has a **density** of 0.11, as compared to 0.01 for the full ICT business network. Thus, Darmstadt's ego network is significantly denser than that of the full ICT business network. An average node in Darmstadt's ego network is better connected than an average node in the full network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Darmstadt's ego network scores 0.618, which is higher than the score for the full ICT business network. This indicates that the regions in Darmstadt's ego network are clustered into much more tightly connected groups than the regions in the full ICT business network.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. Darmstadt's ego network scores 0.905, as compared to 0.271 for the full ICT business network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in Darmstadt's ego network than between the nodes in the full network in terms of their position in the network. This might indicate that, for example, in the ego network there are very few nodes with high levels of centrality and numerous nodes that play less central roles.

The **distance**[50] between any two nodes in Darmstadt's ego network, measured by the average path length, is 1.9, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT business network.

[50] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

The **average number of direct neighbours** of the regions included in the Darmstadt's ego network is 14, i.e. only 75% of the same number for the full ICT business network, where an average node has 19 partners. This shows that the Darmstadt's ego network is composed of small and less central nodes.

Table 60: Characteristics of Darmstadt's network vs. full ICT business network

Network-Level Measure	Full ICT business network	Darmstadt's ego network
Node Count	1,840	135
Link Count	18,180	1,133
Density	0.010	0.109
Clustering Coefficient	0.408	0.618
Network centralization	0.271	0.905
Average path length	2.817	1.891
Average number of neighbours	18.641	14.563

Darmstadt's top 20 partners in the ICT business network by in- and out-degree

Table 61 lists Darmstadt's top 20 partners in the ICT business network by two measures in the ICT business network. The first, i.e. in-degree, tells us about the number of affiliates located in Darmstadt and owned by ICT Scoreboard companies headquartered in other regions in the world. The second, i.e. out-degree, refers to the number of affiliates owned by ICT Scoreboard companies headquartered in Darmstadt and located in other regions around the world.

Regarding the in-degree ranking, the top 20 regions (of 111 in total), in which there is at least one ICT Scoreboard company with affiliates in Darmstadt, account for 154 affiliates altogether, i.e. 57% of all ICT Scoreboard affiliates located in Darmstadt. ICT Scoreboard companies with affiliates in Darmstadt are from München, Berlin and Karlsruhe and the rest of Germany.

Concerning the out-degree ranking, the top 20 regions (of 35 in total) in which there is at least one affiliate of an ICT Scoreboard firm headquartered in Darmstadt, account for altogether 42 affiliates. This represents 74% of affiliates owned by Darmstadt ICT Scoreboard companies and located outside of Darmstadt. The main business destinations of Darmstadt ICT Scoreboard companies include Bonn, München, and Düsseldorf.

Thus, while Darmstadt is an important business destination of mainly German ICT Scoreboard companies, ICT Scoreboard companies headquartered in Darmstadt have a significant number of their affiliates outside of Germany, e.g. Finland, UK, and outside of Europe, e.g. US.

Table 61: Darmstadt's top 20 partners in the ICT business networkby in- and out-degree

In-degree: Number of affiliates located in Darmstadt and owned by ICT Scoreboard companies headquartered in ...				Out-degree: Number of affiliates owned by ICT Scoreboard companies headquartered in Darmstadt and located in ...			
Nr	**Region Code**	**Region name**	**Nr**	**Nr**	**Region Code**	**Region name**	**Nr**
1	DE212	München, Kreisfreie Stadt	24	1	DEA22	Bonn, Kreisfreie Stadt	7
2	DE300	Berlin	19	2	DE212	München, Kreisfreie Stadt	4
3	DE122	Stadtkreis Karlsruhe	13	3	DEA11	Düsseldorf, Kreisfreie Stadt	3
4	DE600	Hamburg	13	4	DE712	Frankfurt am Main	3
5	DE111	Stuttgart, Stadtkreis	11	5	FI181	Uusimaa	3
6	DEA23	Köln, Kreisfreie Stadt	10	6	US1914	O'Brien County, IA	3
7	DEA11	Düsseldorf, Kreisfreie S.	8	7	DEA1C	Mettmann	2
8	DEA52	Dortmund, Kreisfreie Stadt	8	8	DEA21	Aachen, Kreisfreie Stadt	2
9	DE712	Frankfurt am Main	6	9	NL326	Groot-Amsterdam	2
10	DED31	Leipzig, Kreisfreie Stadt	6	10	UKI12	Inner London East	2
11	DE21H	München, Landkreis	5	11	DE118	Heilbronn, Landkreis	2
12	DE254	Nürnberg, Kreisfreie Stadt	4	12	DE300	Berlin	1
13	DEA1C	Mettmann	4	13	DE122	Stadtkreis Karlsruhe	1
14	DEA27	Rhein-Erft-Kreis	4	14	DE600	Hamburg	1
15	DEA51	Bochum, Kreisfreie Stadt	4	15	DE21H	München, Landkreis	1
16	AT130	Wien	3	16	AT130	Wien	1
17	DE21C	Fürstenfeldbruck	3	17	DE21C	Fürstenfeldbruck	1
18	DE21L	Starnberg	3	18	DE21B	Freising	1
19	DE261	Aschaffenburg, Kreisfreie Stadt	3	19	DE718	Hochtaunuskreis	1
20	DE264	Aschaffenburg, Landkreis	3	20	FR105	Hauts-de-Seine	1
Total top 20			**154** (57% in total)	**Total top 20**			**42** (74% in total)
Total			**272**	**Total**			**57**

4.5 Conclusions

This section presents a short summary of the key findings on the ICT activity in Darmstadt according to the framework depicted in **Figure 2**.

ICT R&D

Concerning the **agglomeration of ICT R&D** activity, one can see that Darmstadt, despite its size - i.e. around 150,000 inhabitants, has a wide variety and concentration of ICT R&D activity. For example, although there is only one university in Darmstadt, Technische Universität Darmstadt, which is ranked in the QS World University Ranking, it gives this small German region (given its share in the total EU population), 2nd place among all the European regions for QS ranked universities. This same university is also responsible for considerable scientific output in the ICT field amounting to around 1% of the EU total. Moreover, the quality of this scientific performance is

recognized in the academic world. This small region also ranks very high in terms of FP7 funding and participation in FP7 programmes. This can be attributed to the activity of the prominent Darmstadt University and private organizations, such as Zentrum für Graphische Datenverarbeitung, Siemens AG, Merck Chemicals and Software AG, and SMEs. Furthermore, this ICT R&D landscape is complemented by large R&D expenditures, the majority of which are controlled by the largest ICT company in the region, e.g. Software AG.

Regarding **ICT R&D internationalisation**, Darmstadt cannot be said to be an important location for the ICT R&D activity of foreign firms, at least among those that are considered to be the major influencers of semiconductor design (IHS iSuppli criteria).

Darmstadt is a small node in the **ICT R&D network,** but still belonging to the top 100 main nodes (or top 10%). One of the key characteristics of its network position is that it plays an important intermediary role, bringing together nodes that are in different parts in the network. A closer look at the composition of its neighbourhood, i.e. regions to which it is linked directly, shows that it is very well connected with the majority of the key nodes, and it also maintains strong links with less central and smaller nodes. As a result, together with its direct partners, Darmstadt forms a small but very densely connected web of linkages. This region belongs to a small and specialized part of the ICT R&D network. Hence it seems to play its role, which is likely to be related more to its specific characteristics and interests than to its size.

ICT Innovation

In terms of **ICT Innovation agglomeration**, Darmstadt ranks very high, as compared to other European regions. This is exemplified by such indicators as investments into intangibles by ICT firms or the output of R&D activity measured by the number of ICT patents. One of the economic consequences of these activities is the fact that this small German region attracts a comparatively large number of venture capital deals. These deals target newly funded companies that occupy technological niches which seem to be very strongly influenced by the business environment of Darmstadt. Examples of funded activities include the development of system solutions based on electrorheological technology for industry and the automotive sector; software for sophisticated, intelligent Machine Vision systems; and graphical data processing.

With respect to **ICT Innovation internationalisation**, this small German region exhibits a very high level of international collaboration in ICT inventive activity. This is based on the observation that over 30% of all inventions developed in Darmstadt are a result of international collaboration. In ICT co-inventing activities, Darmstadt-based inventors are mainly partnered by inventors from Japan, the US, France, Austria and the Netherlands. This high level of international collaboration can be seen as an efficient strategy compensating the effects of the small size of the region.

Darmstadt is strongly embedded in the **ICT innovation network**. Inventors based in Darmstadt maintain many connections that go beyond the region's borders. Moreover, due to the characteristics of these connections and Darmstadt's resulting position in the network, the region plays a strong intermediary role between various groups in the network. Although its major partners include inventors residing in other German regions, Darmstadt has far reaching links with, for instance, Japan.

ICT business

Considering its size, Darmstadt shows strong **ICT business agglomeration**. Moreover, this business landscape is very diverse and includes the presence of Software A.G., the second largest software vendor in Germany, with a large number of affiliates around the world. It also includes a large number of smaller and fast growing firms. The economy of the region continues to be very dynamic: over the last decade, Darmstadt has attracted a large number of new enterprises and has become Europe's Nr 1 in terms of investments by ICT firms (in relative terms).

Darmstadt exhibits a high level of **ICT Business internationalisation**. The high level of inward and outward ICT business internationalisation shows that local companies maintain strong

connections with other countries and also that it is an important place for doing business for foreign companies. Among the main foreign investors in Darmstadt are US, Japanese, Dutch, British and Belgian firms.

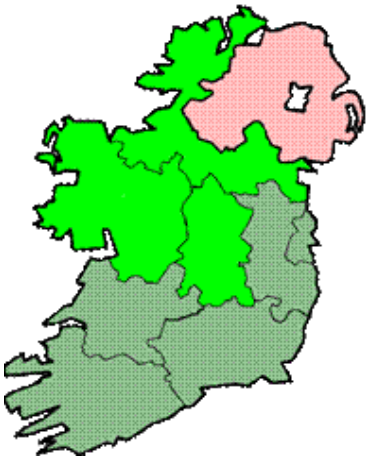
Darmstadt is well embedded in the **ICT business network**. This is mainly the result of the activity of Software AG, which has a large number of affiliates in other regions worldwide. However, a large number of Software AG's affiliates are located within Germany. Moreover, the network partners are small and less central nodes than Darmstadt. Due to this national orientation, the region occupies an important, but less central position in the ICT global business network than the one it occupies within the German one.

Summing up, Darmstadt can be considered as an important element of the European and global ICT landscape. The sound ICT R&D activity and the inventive output together with its rich ICT business environment make it stand out from other European regions, despite its size.

5. Dublin

This case study presents and analyses the available data gathered throughout the EIPE study about the **Dublin region** (code IE021). It is a NUTS3 level[51] region of Europe.

It is part itself of a broader region named Southern and Eastern (IE) (IE 02, shaded in darker green on the map of Ireland), a NUTS 2 level region with the 21st highest level GDP per capita in Europe (Eurostat, 2013).



The Dublin region, shown below, is composed of the capital City, Dublin, and numerous other cities: Swords, Balbrigan, Malahide, Skerries, Portmarnock, Rush, Donabate, Lusk, etc. The Dublin region

has a population of around 1.2 million inhabitants, out of which around 1 million live in Dublin city.

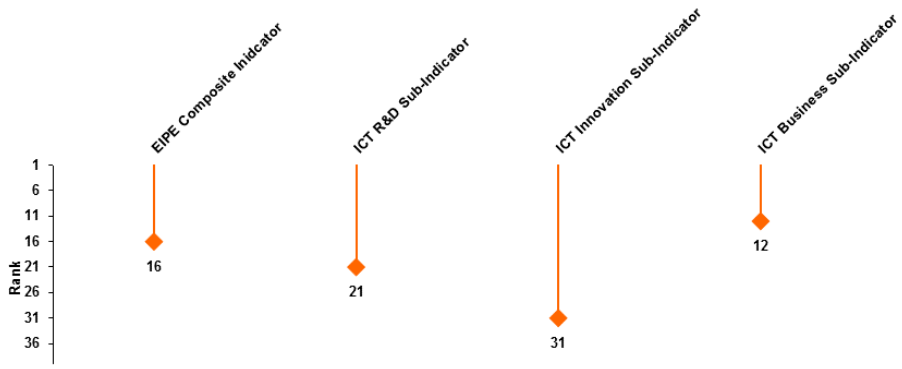
Henceforth, the report often uses the term "Dublin" to refer to the **Dublin Region**.

[51] Nomenclature of Territorial Units for Statistics (NUTS). For a list of the European statistical regions see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction. Source of the map: Wikipedia.

5.1 Dublin in the EIPE ranking

Dublin (IE021) reached the 16th place among 1303 regions in Europe according to the EIPE composite indicator (**Figure 19**). It is surpassed by such regions as Hauts-de-Seine, Milano and Berlin (see **Figure 3**). The figure also shows Dublin's position by individual sub-indicators. According to this information, Dublin comes 21st in R&D, 31st in innovation and 12th in business activity.

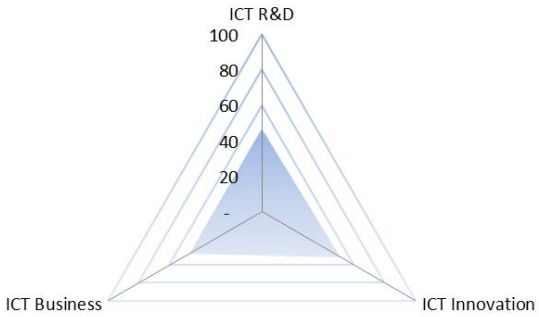
Figure 19: Dublin in the EIPE ranking by EIPE composite indicator, ICT R&D, Innovation and Business sub-indicators



Note: The graph shows the performance of Dublin in the overall EIPE ranking and the ICT R&D, ICT Innovation and ICT Business ranking. The scale represents the rank in comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

Its relative performance in all three domains, i.e. ICT R&D, ICT Innovation and ICT Business is depicted in **Figure 20**. This figures shows that Dublin, in comparison with the remaining 1302 EU NUTS 3 regions, has a rather balanced performance between ICT R&D, Innovation and Business activities.

Figure 20: Performance of Dublin in ICT R&D, Innovation and Business



Note: The graph represents the performance of Dublin in the ICT R&D, ICT Innovation and ICT Business rankings. The scale represents normalized scores with maximum 100 and minimum 0. The rankings are based on the analysis of 1303 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

A more detailed picture of Dublin's rankings in each of the 42 indicators, i.e. the Dublin EIPE ID card, is presented **Table 62**. In the following sections, information for each of these indicators is given. Thus, a detailed picture of the ICT activity in Dublin, fully based on the data collected during the study to construct the 42 indicators, is offered.

Table 62: Dublin EIPE ID card

Activity	Characteristic	Name of Indicator	Indicator ID	Rank
R&D	Agglomeration	Universities ranked in the QS University Ranking	AgRD 1	27
		Academic ranking of a Computer Science faculty	AgRD 2	20
		Employer ranking of a Computer Science faculty	AgRD 3	12
		Citations ranking of a Computer Science faculty	AgRD 4	5
		R&D expenditures by ICT firms	AgRD 5	92
		FP7 funding to private organisations	AgRD 6	65
		FP7 participations	AgRD 7	55
		FP7 funding to SMEs	AgRD 8	65
		FP7 participations by SMEs	AgRD 9	55
		Location of ICT R&D centres	AgRD 10	67
		Ownership of ICT R&D centres	AgRD 11	21
		Scientific publications in Computer Science	AgRD 12	77
	Internationalisation	Outward ICT R&D internationalisation	IntRD 1	21
		Inward ICT R&D internationalisation	IntRD 2	47
	Networking	Degree in ICT R&D network	NetRD 1	28
		Closeness centrality in ICT R&D network	NetRD 2	28
		Betweenness centrality in ICT R&D network	NetRD 3	26
		Eigenvector centrality in ICT R&D network	NetRD 4	27
Innovation	Agglomeration	Investment in intangibles by ICT firms	AgIn 1	124
		Venture Capital financing to ICT firms	AgIn 2	5
		ICT patents	AgIn 3	252
	Internationalisation	International co-inventions	IntIn 1	298
	Networking	Degree in ICT innovation network	NetIn 1	60
		Closeness centrality ICT innovation network	NetIn 2	33
		Betweenness centrality ICT innovation network	NetIn 3	69
		Eigenvector centrality ICT innovation network	NetIn 4	182
Business	Agglomeration	Location of ICT Scoreboard Headquarters	AgBuss 1	48
		Ownership of ICT Scoreboard affiliates	AgBuss 2	23
		Location of ICT Scoreboard affiliates	AgBuss 3	3
		Location of ICT firms	AgBuss 4	21
		ICT employment	AgBuss 5	143
		Growth in ICT employment	AgBuss 6	1295
		Turnover by ICT firms	AgBuss 7	156
		Growth in turnover by ICT firms	AgBuss 8	1299
		New business investments in the ICT sector	AgBuss 9	11
	Internationalisation	Outward ICT business internationalisation	IntBuss 1	24
		Inward ICT business internationalisation	IntBuss 2	1
	Networking	In-degree in ICT business network	NetBuss 1	7
		Out-degree in ICT business network	NetBuss 2	18
		Closeness centrality in ICT business network	NetBuss 3	17
		Betweenness centrality in ICT business network	NetBuss 4	19
		Eigenvector centrality in ICT business network	NetBuss 5	3

Note: The table reports the performance of Dublin in each out of the 42 indicators used in the EIPE ranking and grouped around three dimensions, i.e. ICT R&D, ICT Innovation and ICT Business. The scale represents the rank in the comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

5.2 ICT R&D

This section sheds light on Dublin's performance in ICT R&D activities. It proceeds by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. Detailed background information on the ranking of Dublin by the R&D indicators listed in this region's EIPE ID card can be found in **Table 62**. The next sections analyse the ICT R&D activities in Dublin by looking at their following characteristics:

- ICT R&D Agglomeration (AgRD), i.e. performance of universities and research organisations; private and public ICT R&D expenditures and the location of ICT R&D centres (Section 0),
- ICT R&D Internationalisation (IntRD), i.e. the number of ICT R&D centres located outside Ireland that are owned by companies with headquarters located in Dublin (outward internationalisation) and the number of ICT R&D centres located in Dublin that are owned by foreign companies (inward internationalisation) (Section 0),
- ICT R&D Networking (NetRD), i.e. linkages formed by research organizations located in Dublin when they participate in joint FP7 programmes with organizations located in other regions (Section 0).

5.2.1 ICT R&D Agglomeration (AgRD)

The analysis of the ICT R&D Agglomeration in Dublin starts by providing a snapshot on the universities and the bibliometric output of organizations located in the region (see Table 63). This information is based on the QS World University Rankings (reference year 2008) and the Thomson Reuters Web of Knowledge (reference years 2000-2012). For the methodology of indicators construction see Section 0.

Table 63: ICT R&D Agglomeration: Universities & bibliometrics

Indicator ID	Name of indicator	Rank	Dublin universities in QS university ranking	
AgRD 1	**Universities ranked in the QS University Ranking**	27	1. University College Dublin 2. Trinity College Dublin	
			The best performing Computer Science faculty of a Dublin university according to the ...	
AgRD 2	**Academic ranking of a Computer Science faculty**	20	Trinity College Dublin	
AgRD 3	**Employer ranking of a Computer Science faculty**	12	University College Dublin	
AgRD 4	**Citations ranking of a Computer Science faculty**	5	University College Dublin	
AgRD 12	**Scientific publications in Computer Science**	77	**Total number of publications**	**% in EU total**
			1,044	1%
			Research organizations with the highest number of publications, number of publications in brackets	
			1. University College Dublin (599) 2. Trinity College Dublin (445)	

Dublin has two universities included in the QS ranking, i.e. University College Dublin and Trinity College Dublin. Taking into account its share in the total EU population, Dublin ranks 27th for universities among all European regions.

A closer look at the specific performance of individual computer science faculties shows that in comparison with faculties of this kind in other European regions, University College Dublin scores high in the citations and employer ranking, i.e. 5th and 12th respectively. The Computer Science faculty of the Trinity College Dublin is among the 20 best faculties in Europe.

As regards the indicator "scientific publications in Computer Science", the research organisations based in Dublin, produced over 1044 publications (1% of EU total) between 2000 and 2012 (as registered by Thomson Reuters). Considering Dublin's share in the EU population, this results in a 77th place in this ranking. Two universities located in Dublin, i.e. University College Dublin and Trinity College Dublin, account for all the publications.

Regarding public ICT R&D expenditures, they are proxied here by FP7 funding data attributed to research projects in which private and/or public organizations, based in Dublin, participated in the time period between 2007 and 2011 (see **Table 64**).

Given its share in the total EU population, Dublin ranks 65th in the EU as regards FP7 funding to organizations. Between 2007 and 2011, organizations based in Dublin received 91 M Euro for FP7 projects. This represents 0.78% of the total EU ICT FP7 funding. The five organizations that received the highest amount of funding there were four higher education institutions, i.e. Trinity College Dublin, Dublin City University, University College Dublin and National College of Ireland and one research institute, i.e. Dublin Institute of Technology.

Dublin ranks also 55th among the European regions (again taking into account its share in the total EU population) with respect to the number of participations in FP7 projects. Between 2007 and 2011, organizations based in Dublin participated in 255 FP7 projects. This represents 0.85% of all FP7 projects in this period. The organizations that participated in the highest number of FP7 projects were four of those mentioned above, i.e. Trinity College Dublin, Dublin City University, National College of Ireland and Dublin Institute of Technology and a private company of US origin, i.e. Google Ireland. Altogether they participated in over 48% of all the projects granted to organizations based in Dublin.

Dublin, given its share in the total EU population, ranks 55th among all the European regions for the amount of FP7 funding granted to SMEs. Between 2007 and 2011, SMEs based in Dublin received 20 M Euro for FP7 projects. This represents 0.82% of the total EU ICT FP7 funding to SMEs. A similar picture emerges when we look at the number of participations to FP7 project by SMEs based in Dublin. Here, again, one can see that, given its share in the total EU population, Dublin ranks 55th among all the European regions. Dublin—based SMEs were involved in 60 FP7 projects, i.e. 0.83% of FP7 projects to which SMEs participated Europe-wide.

Thus, taking into account the share of FP7 funding i.e. 0.78% in the EU total, and the rate of participation to FP7 projects by organizations based in Dublin, i.e. 0.85% in the EU total, organizations based in this region show a lower level of FP7 funding, as compared to the their participation share.

Table 64: ICT R&D Agglomeration: FP7 funding and participation

Indicator ID	Name of indicator	Rank		
AgRD 6	FP7 funding	65	**Total amount of funding (in M of Euro)**	**% in EU total**
			91	0.78%
			Research organizations based in Dublin with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			1. Trinity College Dublin (22) 2. DUBLIN CITY UNIVERSITY (13) 3. UNIVERSITY COLLEGE DUBLIN NATIONAL UNIVERSITY (7) 4. DUBLIN INSTITUTE OF TECHNOLOGY (3) 5. NATIONAL COLLEGE OF IRELAND (2)	
AgRD 7	FP7 participations	55	**Number of participations**	**% in EU total**
			255	0.85%
			Research organizations based in Dublin with the highest number of participations in FP7 projects, number of participations in brackets	
			1. TRINITY COLLEGE DUBLIN (50) 2. DUBLIN CITY UNIVERSITY (32) 3. NATIONAL UNIVERSITY OF IRELAND DUBLIN (23) 4. GOOGLE IRELAND LTD (11) 5. DUBLIN INSTITUTE OF TECHNOLOGY (7)	
AgRD 8	FP7 funding to SMEs	65	**Total amount of funding (in M of Euro)**	**% in EU total**
			20	0.82%
			SMEs based in Dublin with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			1. EDNA PASHER PHD AND ASSOCIATES (2.0) 2. IIMC INTERNATIONAL INFORMATION MANAGEMENT CORP. (1.4) 3. SILANSYS SEMICONDUCTOR LIMITED (1.1) 4. NTERA (0.9) 5. INTUNE NETWORKS LIMITED (0.7)	
AgRD 9	FP7 participations by SMEs	55	**Number of participations**	**% in EU total**
			60	0.83%
			SMEs based in Dublin with the highest number of participations in FP7 projects, number of participations in brackets	
			1. EDNA PASHER PHD AND ASSOCIATES (3) 2. IIMC INTERNATIONAL INFORMATION MANAGEMENT CORP. (3) 3. INTUNE NETWORKS LIMITED (3) 4. EUROPEAN BIOMETRIC FORUM LIMITED (2) 5. HAPTICA (2)	

Information on average annual expenditures on R&D by ICT firms and on the location and ownership of ICT R&D centers is used to provide further details on ICT R&D agglomeration (see **Table 65**). Data on the average annual amount spent on R&D in the ICT sector for the period 2005-

2011 originate from the ORBIS database developed by Bureau Van Dijk. Data on the location and ownership of ICT R&D centres[52] is for 2012 and stems from the Design Activity Tool developed by IHS iSuppli, an industry consultancy which specialises in observing the ICT sector.

Considering R&D centres, there are 9 R&D facilities belonging to *major semiconductor influencers*. Taking into account its share in the EU population, Dublin comes 67th at EU level. These R&D centres located in Dublin belong to such multinational companies as ABB, Alcatel-Lucent, Avaya, Ericsson and Hewlett-Packard.

According to IHS iSuppli, in 2012 there were no companies that could be considered as *major semiconductor influencers*, with headquarters located in Dublin. Hence, with respect to the ownership of R&D centres, Dublin ranks 21st, sharing this position with other regions where no such companies were identified by IHS

Table 65: ICT R&D Agglomeration: R&D expenditures and R&D centres

Indicator ID	Name of indicator	Rank		
AgRD 5	R&D expenditures by ICT firms	92	**Total amount of funding (in M of Euro)**	**% in EU total**
			n.a.	n.a.
			R&D investors based in Dublin with the highest amount of R&D expenditures	
			1. ADOBE SOFTWARE TRADING COMPANY LIMITED 2. KN NETWORK SERVICES HOLDINGS LIMITED 3. LAB49 CONSULTING LIMITED 4. AEPONA GROUP LIMITED 5. DATALEX PLC	
AgRD 10	Location of ICT R&D centres	67	**Number of R&D centres located in Dublin**	**% in EU total**
			9	1%
			Firms with the highest number of R&D centres located in Dublin	
			1. ABB 2. Alcatel-Lucent 3. Avaya 4. Ericsson 5. Hewlett-Packard	
AgRD 11	Ownership of ICT R&D	21	**Number of R&D centres owned by firms based in Dublin**	**% in EU total**
			n.a.	n.a.
			Firms based in Dublin with the highest number of R&D centres owned worldwide	
			n.a.	

5.2.2 ICT R&D Internationalisation (IntRD)

The analysis of ICT R&D Internationalisation in Dublin is based on data on the location and ownership of R&D centres for 2012 provided by the Design Activity Tool (published by HIS iSuppli, an industry consultancy which specialises in the ICT sector). For the indicator construction

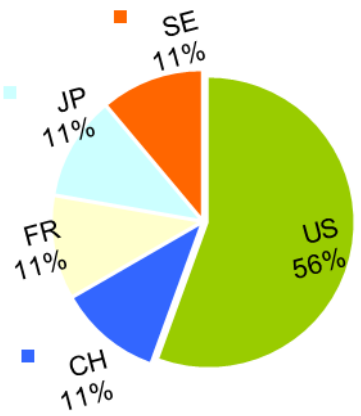
[52] Those R&D Centres belong to the firms considered as major semiconductors influencers by HIS iSuppli.

methodology, see Section 0. The information on ICT R&D internationalisation in Dublin is presented in **Table 66**.

For the outward ICT R&D internationalisation indicator, Dublin ranks 21st. The indicator is proxied by the number of ICT R&D centres located outside of Ireland and that are owned by companies headquartered in Dublin (IHS definition), As already noted in the previous section (see **Table 65**), there are no major semiconductor influencers in Dublin. Hence, this region shares the 21st rank with all other European regions where there are no such companies.

In terms of inward ICT R&D internationalisation, which is proxied by the number of ICT R&D centres located in Dublin and owned by major semiconductor influencers (IHS definition)located outside of Ireland, Dublin ranks 47th. The major semiconductor influencers of foreign origin (see **Table 65**), own altogether 9 R&D centres that are based in Dublin. The countries of origin of these companies are the US, Switzerland, France, Japan and Sweden.

Table 66: Outward and inward R&D internationalisation

Indicator ID	Name of indicator	Rank	
InRD 1	Outward ICT R&D internationalisation	21	**Number of ICT R&D centres located outside of Ireland that are owned by companies' headquarters located in Dublin**
			n.a.
			Top locations of R&D centres owned by firms from Dublin
			n.a.
InRD 2	Inward ICT R&D internationalisation	47	**Number of ICT R&D centres located in Dublin that are owned by foreign companies**
			9
			Origins of companies with R&D centres located in Dublin
			

5.2.3 ICT R&D Networking (NetRD)

In order to construct an ICT R&D network and to assess the position of individual regions in it, we rely on data on participation in the ICT part of the FP7 programme. All NUTS3 regions where FP7 ICT R&D programme partners are located are identified as nodes of the network. Bilateral relationships

(arcs of the network) between regions exist whenever an organisation from one region participates in a FP7 ICT R&D programme together with an organization from a different region.[53] This allows us to construct a set of network measures for each region and the analysis of these measures for Dublin is presented below.

Analysing the network of collaborations in the FP7 ICT R&D programme allows us to see Dublin's specific position in the EIPE ranking and better understand its high position and the role it plays in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Dublin's position in the ICT R&D network, as observed from the collaborative links established by the organisations located in Dublin with organisations located in other European regions, and the characteristics of these links,
- The characteristics of Dublin ego network[54] formed by its first degree partners in the ICT R&D network,
- Dublin's list of Top 20 partners in the ICT R&D network and the total number of joint projects with each.

For the methodology for indicators construction see Section 0.

Dublin's position in the ICT R&D network

Table 67, which presents Dublin's ranking in the ICT R&D network, confirms the rather strong and central role Dublin plays in the ICT R&D network, but with the following nuances:

- Dublin comes 28th out of 761 regions in the degree ranking. This indicator is based on the number of collaborations a given region maintains with other regions in the ICT R&D network. Research organizations based in Dublin participated in 1603 FP7 projects between 2007 and 2012. Dublin is directly connected with 304 regions (nearly 40% of the all the regions) that participated in the ICT R&D network, which is a high score. In the degree ranking. Dublin is surpassed, by for example, Warwickshire (26th), Thessaloniki (27th) and Graz (28th) and immediately followed by Valencia (29th), Trento (30th) and Warszawa (31st).
- Dublin also comes 28th in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance from other nodes in the network. It shows that Dublin is **a region that is close** to the remaining 760 regions in the ICT R&D network. Again, the regions that immediately proceed and follow Dublin in the closeness centrality ranking are the same ones as in the degree ranking.
- Dublin comes 26th in the betweenness ranking which reflects the position of a node as a hub in the network. Thus, it shows some strength as **an intermediary role** between other nodes of the ICT R&D network. Comparatively to other regions, Dublin is surpassed, by for example, Grande Porto (28th), Aachen (29th) and Irakleio (30th) and immediately followed by Budapest (32nd), Thessaloniki (31st) and Bucuresti (33rd).
- Dublin comes 27^{h} in the Eigenvector centrality ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT R&D network. Thus, despite not being one of the hubs of the network, Dublin's **neighbours seem to be very well-**

[53] For more details on the methodology of constructing a network and its application to ICT R&D, see section 0.

[54] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

connected nodes. Comparatively to other regions, in the Eigenvector centrality ranking, Dublin is surpassed, by for example, Grande Lisboa (24th), Groot-Amsterdam (25th) and Trento (26th) and immediately followed by Warwickshire (28th), Warszawa (29th) and Valencia (30th).

Table 67: Dublin's rankings in the ICT R&D network by network measures

Indicator ID	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	Degree in ICT R&D network	Closeness centrality in ICT R&D network	Betweenness centrality in ICT R&D network	Eigenvector centrality in ICT R&D network
Rank	28	28	26	27

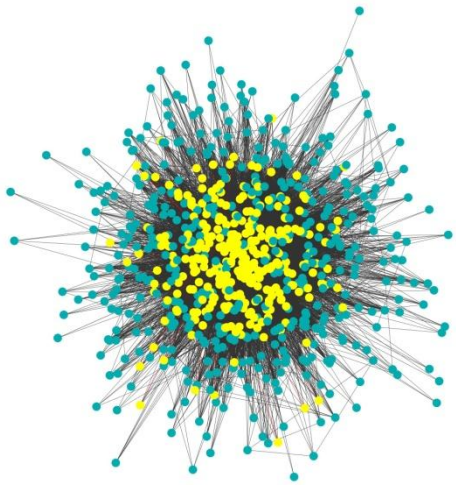
The characteristics of Dublin's ego network

In order to get a deeper insight into the role of Dublin in the ICT R&D network, we have built its *ego network.* Dublin's ego network is a sub-network of the entire ICT R&D network, constructed by taking in account only Dublin's first degree partners (or alters), i.e. nodes directly connected with Dublin and the links among them.[55]

The characteristics of this ego network are then compared with those of the full ICT R&D network to see whether there are some structural differences between the full network and the ego network of the selected node, here Dublin. This way, we can understand better Dublin's neighbourhood in the ICT R&D network and, by casting some light on the attributes of its neighbours, to see how well it is embedded in the ICT R&D network.

An illustration of the full ICT R&D network and its ego network formed by Dublin's first degree partners (yellow nodes) is given in **Figure 21**. **Table 68** summarises the main measures of the Dublin ego network and compares it to the full ICT R&D network.

Figure 21: The ICT R&D network and the ego network of Dublin



Note: The graph represents the full ICT R&D network together with the ego network formed by Dublin's first degree partners represented by yellow nodes.

[55] Ego networks are also known as the neighbourhood networks or first degree neighbourhoods of ego Everett, M. & Borgatti, S. 2005. 'Ego network betweenness.' *Social Networks,* 27:1, 31-38.

According to **Table 68**, Dublin's ego network includes 303 individual regions connected directly to Dublin, i.e. 40% of the regions in the full ICT R&D network. Altogether these regions form nearly 16000 linkages, i.e. 58% of the linkages in the entire network. Thus, the fact that only 40% of the regions in the full network account for nearly two thirds of its all connections indicates that Dublin's neighbours are far better connected than an average node.

This is also confirmed by the density of the Dublin's ego network, which shows how well the network is connected. The Dublin's ego network shows a **density**, i.e. a ratio of the actual number of links to the number of possible links of 0.343, as compared to 0.095 for the full ICT R&D network. Thus, its ego network is significantly denser than that of the full ICT R&D network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. The score of Dublin's ego network is 0.734 and is slightly smaller than of the full ICT R&D network. This indicates that the regions in Dublin's ego network are less clustered as compared to all the regions present in the full ICT R&D network. Nevertheless, due to the high value of the clustering coefficient observed in the Dublin's ego network, also here regions form tightly connected groups.

The **network centralization** level of a network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. Dublin's ego network scores 0.73, whereas the full ICT R&D network scores 0.76. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network. This might, for example indicate, that there are few nodes with very central position in the network and numerous nodes that are less connected nodes and thus play less central roles.

The **distance**[56] between any two nodes in Dublin's ego network, measured by the average path length, is 1.7, as compared to nearly 2 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT R&D network.

The **average number of direct neighbours** of the regions included in the Dublin's ego network is 104, i.e. over 44% more than it is in the in the full ICT R&D network, where an average node has only 72 partners. Thus, the regions in the Dublin's ego network show a higher level of connectedness as compared to the average in the full network.

Table 68: Characteristics of Dublin's network vs. full ICT R&D network

Network-Level Measure	Full ICT R&D network	Dublin's ego network
Node Count	761	305
Link Count	27,490	15,914
Density	0.095	0.343
Clustering Coefficient	0.755	0.734
Network centralization	0.638	0.661
Average path length	1,980	1.657
Average number of neighbours	72	104

[56] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Dublin's Top partners of Dublin in the ICT R&D network

Table 69 gives the list of Dublin's top 20 partners in the ICT R&D network and the number of joint projects carried out with each. In addition, the rankings for each partner in the four network measures are given.

Of the 304 partners with which Dublin maintains direct connections in the ICT R&D network, relationships with **the top 20 partners account for nearly 40%** of all the projects in which organisations located in Dublin were involved. This provides evidence for the existence of strong agglomeration forces in the shaping of the ICT R&D landscape

Regarding the network characteristics of Dublin's top 20 partners, the majority of the projects are conducted with regions which play very strong and central roles in the network. For example, the major partner of Dublin in terms of the number of joint projects is Munchen, the key node in the ICT R&D network by the network measures reported in **Table 69**. The following partners, e.g. Inner London East, Paris, Madrid and Attiki, are similarly important nodes of the ICT R&D network. The presence of, for example, Yvelines with degree rank 22 and Warwickshire with degree rank 25, shows that besides maintaining strong connections with the core of the network, Dublin has strong relationships with some less central nodes. Thus, despite of being a mid-size node in the network, which in addition is distant in geographical terms from other nodes, Dublin is strongly connected with the key players of the ICT R&D in Europe. In addition, by being having strong relationships with less central nodes, it also holds an intermediary position.

Table 69: Top 20 partners of Dublin in the ICT R&D network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint projects**	**Share in total**	**Degree in ICT R&D network**	**Closeness centrality in ICT R&D network**	**Betweennes s centrality in ICT R&D network**	**Eigenvector centrality in ICT R&D network**
1	DE212	Kreisfreie Stadt Munchen	71	4.4%	1	1	1	1
2	UKI12	Inner London East	60	3.7%	4	4	7	5
3	FR101	Paris	57	3.6%	2	2	2	2
4	ES300	Madrid	54	3.4%	3	3	4	3
5	GR300	Attiki	50	3.1%	4	4	6	4
6	ITC45	Milano	48	3.0%	6	6	5	6
7	ITE43	Roma	40	2.5%	7	7	3	7
8	AT130	Wien	25	1.6%	11	11	11	10
9	ES511	Barcelona	23	1.4%	8	8	8	8
10	BE100	Arr. de Bruxelles-Capitale	22	1.4%	10	10	10	11
11	FR103	Yvelines	22	1.4%	22	22	32	19
12	DE122	Stadtkreis Karlsruhe	21	1.3%	12	12	15	15
13	DE111	Stuttgart, Stadtkreis	20	1.2%	24	24	20	23
14	NL414	Zuidoost-Noord-Brabant	20	1.2%	17	17	22	17
15	NL333	Delft en Westland	19	1.2%	18	18	18	21
16	SE110	Stockholms lan	18	1.1%	15	15	12	14
17	UKG13	Warwickshire	18	1.1%	25	25	29	28
18	BE242	Arr. Leuven	17	1.1%	13	13	13	13
19	FI181	Uusimaa	17	1.1%	9	9	9	9
20	FR105	Hauts-de-Seine	17	1.1%	20	20	25	16
Total Top 20			**639**	**39.9%**				
Total			**1603**	**100%**				

5.3 ICT innovation

This section sheds light on Dublin's performance in the ICT innovation activities. It makes use of the information collected within the EIPE project and follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. Dublin EIPE ID card provides detailed information on the background information on this region's ranking by ICT innovation indicators (**Table 62**) ICT Innovation activities in Dublin are analysed by looking at the following characteristics:

- ICT Innovation Agglomeration (AgIn), i.e. investment in intangibles by ICT firms, venture capital financing to ICT firms and ICT patents (Section 0),
- ICT Innovation Internationalisation (IntIn), i.e. the number of ICT inventions developed by inventors located in Dublin and outside of Ireland (Section 0),
- ICT Innovation Networking (NetIn) i.e. the place of Dublin in the ICT innovation network formed by co-inventions jointly developed by inventors located in regions around the world (Section 0).

5.3.1 ICT Innovation Agglomeration (AgIn)

The analysis of the ICT Innovation Agglomeration in Dublin starts with providing information on the amount of investment in intangibles by ICT firms, venture capital funding to ICT firms and the number of ICT patents (see **Table 70**). This data comes from the company-level database ORBIS by Bureau Van Dijk (reference years from 2005 to 2012), Venture Source by Dow Jones (reference years from 2000 to 2012) and REGPAT by OECD-EPO (reference years from 2000 to 2012) respectively. For the methodology for indicator construction see Section 0.

Dublin, given its share in the total EU population, ranks 124th among the European regions with respect to average annual ICT firms investment by ICT firms in intangibles. According to the company-level database ORBIS by Bureau Van Dijk, in the period 2005-2011, ICT firms based in Dublin spent on average 0.01 M Euro annually on intangibles. Among ICT firms based in Dublin that showed the highest investments in intangibles are, for example, Zamano, Datalex and Adobe.

Regarding the number of venture capital deals to ICT firms, Dublin ranks 5th among all the EU regions. Between 2000 and 2012, there were nearly 1000 VC deals were made with ICT firms based in Dublin. The examples of funded companies include, among others, FleetMatics, a provider of fleet management solutions delivered as software-as-a-service; Openet Telecom, a developer of transaction management software for network operators; or Cape Clear Software, a vendor of enterprise service bus (ESB) software.

ICT innovation output is measured by the number of ICT patents. Organisations based in Dublin produced 370 (0.3% of EU total) patented ICT inventions between 2000 and 2012. This figure and Dublin's share in the EU population puts the region in 298th place in this ranking.

Table 70: ICT Innovation agglomeration in Dublin

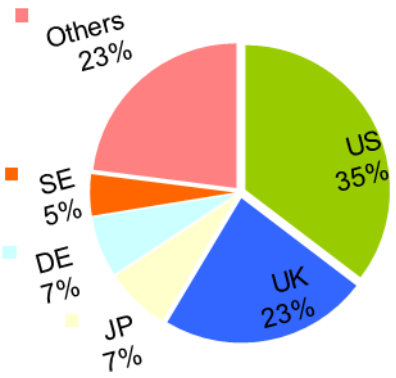
Indicator ID	Name of indicator	Rank		
AgIn 1	Investment in intangibles by ICT firms	124	**Total amount of (in M of Euro)**	**% in EU total**
			0.01	0.00%
			Top investors in intangibles by firms based in Dublin	
			1. ZAMANO PUBLIC LIMITED COMPANY 2. DATALEX PLC 3. ADOBE SOFTWARE TRADING COMPANY LIMITED 4. KN NETWORK SERVICES HOLDINGS LIMITED 5. LAB49 CONSULTING LIMITED	
AgIn 2	Venture Capital financing to ICT firms	5	**Number of VC financial deals to firms based in Dublin**	**% in EU total**
			999	4%
			Organizations with the highest amount of VC funding	
			1. FleetMatics Group Ltd. 2. Openet Telecom Ltd. 3. Cape Clear Software 4. Orbiscom 5. Parthus Technologies	
AgIn 3	ICT patents	252	**Total number of ICT patents**	**% in EU total**
			370	0.3%

5.3.2 ICT Innovation Internationalisation (IntIn)

The analysis of ICT Innovation internationalisation in Dublin is based on the data on ICT international co-inventions, i.e. the number of patents with an inventor residing in Dublin and at least one inventor residing outside Ireland. The data originates from REGPAT (source: OECD-EPO) and covers the period from 2000 to 2012. For the methodology for indicator construction see Section 0.

According to the information presented in **Table 71**, of the total 370 ICT inventions that included Dublin-based inventors, 150 were an output of international collaboration involving partners from outside of Ireland. This gives Dublin a 298th place in the current ranking. The main external partners in ICT co-inventing activity of Dublin-based inventors were from the US, the UK, Japan, Germany and Sweden.

Table 71: ICT innovation internationalisation of Dublin

Indicator ID	Name of indicator	Rank	
IntIn 1	International co-inventions	298	**Number of international ICT co-inventions**
			150
			Top countries by the number of co-inventions between inventors located in Dublin and ...
			

5.3.3 ICT Innovation Networking (NetIn)

In order to construct an ICT innovation network and to assess the position of individual regions in it, we rely on the network analysis of the locations of inventors residing in different regions of the world (3646 regions in total) and jointly developing ICT inventions for which a patent application has been introduced (period 2000-2009). The relationship between two different locations can be described as the total sum of co-inventions developed by inventors residing in these two regions (Guellec and Van Pottelsberghe de la Potterie 2001).

We identify all regions where inventors are located as nodes of the network. Bilateral relationships (arcs of the network) exist between regions whenever an inventor from one region co-developed an invention with an inventor based in a different region.[57] These definitions allow us to construct a set of network measures for each region: the analysis of those measures in the case of Dublin is presented below.

Analysing this network of inventor collaborations in technology development allows us to observe the specific position of Dublin in the ICT innovation network, as compared to other European regions. It also enables us to better understand its position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Dublin's position in the ICT innovation network, as observed from the collaborative links established by inventors located in Dublin with inventors located in other regions around the world, and the characteristics of these links,

[57] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0.

- The characteristics of the ICT innovation ego network[58] of first degree partners of Dublin,
- Dublin's top 20 partners in the ICT innovation network and the number of inventions patented jointly with each.

For the methodology of indicators construction see Section 0.

Dublin's position in the ICT innovation network

Table 72, which presents Dublin's ranking in the ICT innovation network shows that Dublin plays a fairly important role in the ICT innovation network. In particular:

- Dublin comes 60th out of 1189 European regions (out of 3 656 in total worldwide) in the ICT innovation network by the degree indicator. This is based on the number of collaborations a given region maintains with other regions in the ICT innovation network with altogether 3646 regions worldwide through joint co-inventions in the period between 2000 and 2009. Dublin is directly **connected with 250 regions** (7% of all the regions) that participate in the ICT innovation network.
- Dublin also comes 33rd in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Dublin is shown to be **a region in close relations** with the remaining regions of the ICT innovation network, considering the number of its connections.
- Dublin comes 69th in the betweenness ranking, a ranking that reflects the position of a node as a hub in the network. Dublin has **an intermediary node** that links many of the remaining nodes of the ICT innovation network.
- Dublin comes only 182nd in the Eigenvector centrality ranking, reflecting the importance of Dublin based on the role of its neighbours in the ICT innovation network. Thus, Dublin's neighbours seem to be worse-connected than Dublin itself.

Table 72: Dublin's rankings in the ICT innovation network by network measures

Indicator ID	NetIn 1	NetIn 2	NetIn 3	NetIn 4
Indicator Name	Degree in ICT innovation network	Closeness centrality in ICT innovation network	Betweenness centrality in ICT innovation network	Eigenvector centrality in ICT innovation network
Rank	60	33	69	182

The characteristics of Dublin's ego network

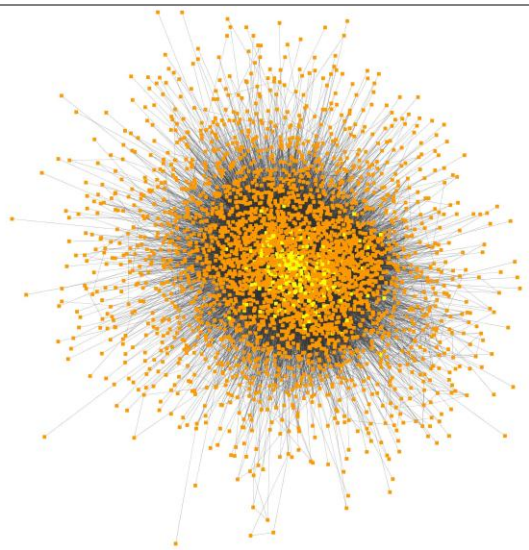
In order to get a deeper insight into the role of Dublin in the ICT innovation network, we have constructed its ego network, i.e. a network consisting of Dublin (ego), the actors it is connected to (alters) and all the links between these alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Dublin ego network is constructed by taking into account only Dublin's first degree partners, i.e. nodes directly connected with Dublin and the links between them.

[58] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

The characteristics of this ego network are compared with those of the full ICT innovation network to see whether there are some structural differences between the full network and the one of the selected node, Dublin, and its direct partners. This comparison will help us to understand better Dublin position in the ICT innovation network. In addition, by casting some light on its neighbours' attributes, it will allow us to see how well the region's neighbourhood network is embedded in the ICT innovation network.

An illustration of the full ICT innovation network and its sub-network formed by Dublin first degree partners (yellow nodes) is given in **Figure 22**. Table 73 summarises the main measures of the Dublin ego network and compares it to the full ICT innovation network.

Figure 22: The ICT innovation network and the ego network of Dublin



Note: The graph represents the full ICT innovation network together with the ego network formed by Dublin's first degree partners represented by yellow nodes.

According to Table 73, Dublin's ego network includes 250 individual regions connected directly to Dublin, i.e. 7% of the regions present in the full ICT innovation network. Altogether these regions form over 9,100 linkages, i.e. 10% of the linkages in the entire network. The fact that such small number of regions account for nearly 10% of the total connections indicates that Dublin's neighbours are better connected than an average node. This is also confirmed by the density measure, i.e. a ratio of the actual number of links to the number of possible links, which shows how well the network is connected. Dublin's ego network shows a **density** of 0.29, as compared to 0.014 for the full ICT innovation network. Thus, the ego network is significantly denser than that of the full ICT innovation network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Dublin's ego network scores 0.66 which is higher than for the full ICT innovation network. This indicates that the regions present in Dublin's ego network are clustered into more tightly connected groups as compared to the other regions in the full ICT innovation network.

The **network centralization** level of a network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. For the Dublin's ego network, it scores 0.71, as compared to 0.3 for the full ICT innovation network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network in terms of their position

in the network. This indicates that there are few nodes with very central position in the network and numerous nodes that play less central roles. This is confirmed by the composition of Dublin's top 20 partners in Table 74, which include both peripheral Irish regions as well as nodes forming the core of the network like Santa Clara County and Tokyo.

The **distance**[59] between any two nodes in the Dublin's ego network, measured by the average path length, is 1.7, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT innovation network.

The **average number of direct neighbours** of the regions included in the Dublin's ego network is 73, i.e. over 63% more than in the in the full ICT innovation network, where an average node has only 52 partners. This confirms that the regions in the Dublin's ego network show a higher level of connectedness than the average in the full network.

Table 73: Characteristics of Dublin's ego network vs. full ICT innovation network

Network-Level Measure	Full ICT innovation network	Dublin's ego network
Node Count	3,646	250
Link Count	94,689	9,114
Density	0.014	0.293
Clustering Coefficient	0.499	0.661
Network centralization	0.320	0.713
Average path length	2.676	1.707
Average number of neighbours	51.941	72.912

Top 20 partners of Dublin in the ICT innovation network

Table 74 lists Dublin's top 20 partners in the ICT innovation network, showing the number of joint patents. In addition, the four network measures are ranked for each partner. Because the list of partners also includes non-EU regions, the ranks of the neighbours are given for the whole network, i.e. including non-EU regions. Hence, this way, the ranks presented here are not comparable with the ranking of the EU regions.

Of the 249 partners with which Dublin maintains direct connections in the ICT innovation network, the relationships with **the top 20 partners account for 65%** of all the co-patents between innovators located in Dublin and other regions. This provides evidence for the existence of strong agglomeration forces that are present in the shaping of the ICT R&D landscape.

Regarding Dublin's top 20 partners, it can be seen that that the majority of the inventors who work together with Dublin's inventors are located in regions that are located near Dublin or in Ireland. For example, the major partners of in terms of the number of joint patents include Mid-East (IE022), South-West (IE025) and Mid-West (IE023). However, what is quite striking is that 11 in the top 200 are regions from the outside of Ireland and Europe. The first three largest non-Irish regions is Santa Clara County (US06085), the core of the Silicon Valley, Tokyo (JPC13), and Hertfordshire (UKH23). Thus, this shows that the role of Dublin as an inter-regional hub in the ICT innovation network is clearly justified.

[59] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Table 74: Dublin's Top 20 partners in the ICT innovation network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint patents**	**Share in total**	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweennes s centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
1	IE022	Mid-East	17.9	24.1%	678	574	803	1700
2	IE025	South-West (IRL)	3.8	5.1%	608	459	970	1123
3	IE023	Mid-West	3.6	4.9%	777	593	1002	1210
4	IE012	Midland	3.4	4.5%	2006	1801	2078	2525
5	US06085	Santa Clara County	3.3	4.4%	1	11	1	16
6	IE013	West	2.5	3.4%	795	597	881	1336
7	IE011	Border	1.9	2.5%	1330	1044	1580	2397
8	JPC13	Tokyo	1.8	2.4%	23	31	42	173
9	IEZZZ	Not classified	1.5	2.1%	1049	1025	504	1855
10	IE024	South-East (IRL)	1.3	1.8%	1474	1040	1750	2386
11	UKH23	Hertfordshire	1.1	1.5%	96	98	145	228
12	US53033	King County, WA	0.9	1.2%	13	20	17	2
13	UKJ11	Berkshire	0.8	1.1%	87	95	134	177
14	US17031	Cook County, IL	0.7	1.0%	10	19	9	61
15	UKM25	Edinburgh, City of	0.7	0.9%	210	250	251	194
16	KR013	Gyeonggi-do	0.6	0.9%	243	192	142	542
17	UKH22	Bedfordshire CC	0.6	0.9%	387	341	638	532
18	DEA19	Solingen, Kreisfreie	0.6	0.8%	752	1290	1197	1044
19	AU105	Sydney	0.6	0.8%	157	108	68	3104
20	UKK14	Swindon	0.6	0.8%	445	461	750	311
Total Top 20			**48.3**	**65.1%**				
Total nr of joint patents			**74.1**	**100%**				

5.4 ICT Business

This section sheds light on Dublin's performance in the ICT business activities by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the second EIPE Report and presented in Figure 2. Detailed background information on the region's rankings for the ICT business indicators is presented in Table 62. (Dublin EIPE ID card). ICT business activities are analysed by looking at the following characteristics:

- ICT Business Agglomeration (AgBuss), i.e. location of ICT Scoreboard companies and their affiliates, location of ICT firms, employment and turnover of ICT firms and new investments in the ICT sector (Section 0),
- ICT Business Internationalisation (IntBuss), i.e. the number of affiliates located outside of Ireland that are owned by ICT Scoreboard companies located in Dublin (outward internationalisation) and the number of affiliates located in Dublin that are owned by foreign ICT Scoreboard companies (inward internationalisation) (Section 0),
- ICT Business Networking (NetBuss), i.e. the position of Dublin in a network formed through linkages between regions around the world based on the location and ownership of ICT Scoreboard affiliates (Section 0).

5.4.1 ICT Business Agglomeration (AgBuss)

The analysis of ICT Business Agglomeration in Dublin starts with the key details on the actors based in Dublin (**Table 75**), their economic performance (**Table 76**) and ends with an overview of new investments in ICT in Dublin (**Table 77**).

This information is based on the company-level information provided by ORBIS by Bureau Van Dijk (reference years from 2005 to 2012)[60] and data collected in the European Investment Monitor by Ernst&Young for the period 1997-2011. For the methodology of indicator construction see Section 0.

Dublin, given its share in the total EU population, ranks 48th among the EU regions for the number of ICT Scoreboard company headquarters it hosts. This is due to the presence of 3 firms that are on the list of the world's top 637 ICT R&D investors. This list includes SkillSoft, a provider of cloud-based learning solutions; Datalex, a provider of travel ecommerce software products; and Norkom, a 25 year old provider of financial crime and compliance software to the global financial services industry. Altogether, these ICT Scoreboard firms own nearly 280 (2% of the EU total) affiliates located worldwide. This, given Dublin's share in the total EU population, gives it the 23rd position in that ranking.

With respect to the affiliates of the 637 ICT Scoreboard Headquarters, 450 of them are in Dublin. In other words, 4% of business affiliates belonging to any ICT Scoreboard Headquarter and based in the EU, are in Dublin. This puts Dublin in 2nd place in this ranking. Considering the location of ICT firms in Dublin, according to the ORBIS company-level database by Bureau Van Dijk, there are 22 ICT businesses (1.8% of EU total) in the capital of Ireland.[61] Given its size, this places Dublin on the 21st place in this ranking.

[60] The information available about business actors that is used here is the following: Location of ICT Scoreboard Headquarters, number of affiliates owned worldwide by ICT Scoreboard Headquarters based in the observed region, number of ICT Scoreboard affiliates located in the observed region and belonging to any of the ICT Scoreboard Headquarter and, finally, number of ICT firms located in the region.

[61] In order to avoid double-counting, separate searches were run using a filter on consolidation code. In the analysis, companies with consolidated accounts only were selected.

Table 75: ICT Business Agglomeration in Dublin

Indicator ID	Name of indicator	Rank		
AgBuss 1	Location of ICT Scoreboard Headquarters	48	**Number of ICT Scoreboard Headquarters located in Dublin**	**% in EU total**
			3	1%
			ICT Scoreboard Headquarters located in Dublin	
			1. SkillSoft 2. Datalex 3. Norkom	
AgBuss 2	Ownership of ICT Scoreboard affiliates	23	**Number of ICT Scoreboard affiliates owned worldwide by ICT Scoreboard Headquarters located in Dublin**	**% in EU total**
			278	2%
AgBuss 3	Location of ICT Scoreboard affiliates	2	**Number of ICT Scoreboard affiliates located in Dublin**	**% in EU total**
			450	4%
AgBuss 4	Location of ICT firms	21	**Number of ICT firms located in Dublin**	**% in EU total**
			22	1.8%

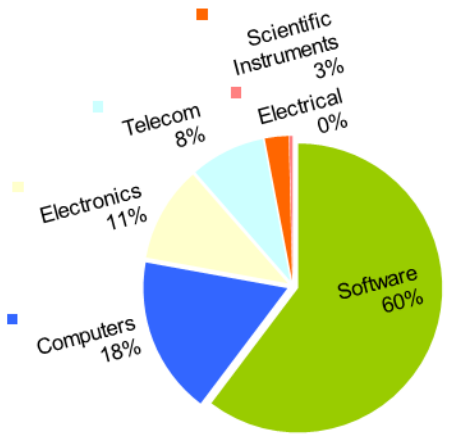
The above-mentioned 22 ICT businesses based in Dublin provide over 0.01% of the total EU employment and generate 0.01% of the total EU turnover of the considered ICT firms (see **Table 76**). Bearing in mind Dublin's share in the total EU population, this puts the region 143rd on employment and 156th on turnover respectively. Also the general level of ICT business activity in Dublin has decreased between 2005 and 2012. In this period, the employment decreased by 30% and turnover by 40%. As a result, Dublin ranks very low in terms of business dynamics among all the EU Nuts 3 regions.

Table 76: ICT Business Agglomeration in Dublin, cont.

Indicator ID	AgBuss 5	AgBuss 6	AgBuss 7	AgBuss 8
Indicator Name	**ICT employment**	**Growth in ICT employment**	**Turnover by ICT firms**	**Growth in turnover by ICT firms**
Rank	143	1295	156	1299
% in EU total / %	0.01%	-30%	0.01%	-40%

According to the information provided by the European Investment Monitor, between 1997 and 2011, there were nearly 262 new investments in Dublin by companies from the ICT sector (see **Table 77**). This constitutes 2% of all investments considered in the entire EU. Given the share of Dublin's population in the total EU population, it comes 11th in this ranking. A large share of these investments were in the field of software (60%), followed by computers (18%) and electronics (14%).

Table 77: ICT Business Agglomeration in Dublin, cont.

Indicator ID	Name of indicator	Rank		
AgBuss 9	New business investments in the ICT sector	11	**Number of new investments in the ICT sector in Dublin**	**% in EU total**
			262	2%
			Distribution of new investments by activity type	
				

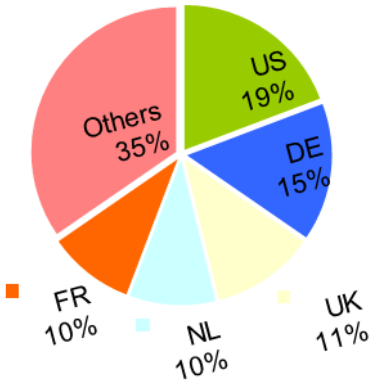
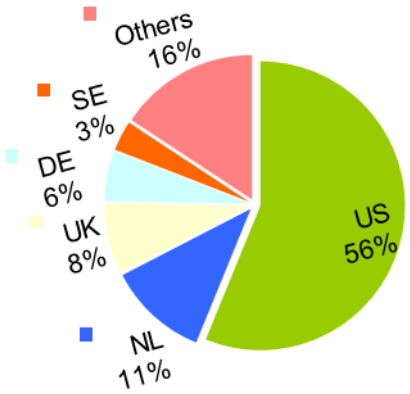
5.4.2 ICT Business Internationalisation (IntBuss)

The analysis of ICT Business Internationalisation is based on the data on the location and ownership of affiliates by 637 ICT Scoreboard Headquarters and refers to 2008. This data comes from the company-level information provided by ORBIS by Bureau Van Dijk. Depending on the perspective, two types of internationalisation are considered, i.e. outward internationalisation measured by the number of affiliates located outside of Ireland that are owned by ICT Scoreboard companies located in Dublin and inward internationalisation measured by the number of affiliates located in Dublin that are owned by foreign ICT Scoreboard companies. For the methodology for indicator construction see Section 0.

Dublin ranks 24th in outward ICT business internationalisation (see **Table 78**). This is due to the fact that out of 278 affiliates owned by the three ICT Scoreboard Headquarters based in Dublin, 117affiliates are located outside Ireland. Their major foreign business activity location includes the US, Germany, the UK, the Netherlands and France.

In terms of inward ICT business internationalisation, Dublin ranks 1st. According to the information provided in **Table 78**, 321 out of 450 affiliates which belong to ICT Scoreboard Headquarters and are located in Dublin are of foreign ownership. 56% of all foreign affiliates belong to the US ICT Scoreboard Headquarters. Other major owners are based in the Netherlands, the UK, Germany and Sweden.

Table 78: Outward and inward ICT business internationalisation

Indicator ID	Name of indicator	Rank	
InBuss 1	Outward ICT business internationalisation	24	**Number of affiliates located outside of Germany that are owned by ICT Scoreboard Headquarters located in Dublin**
			117
			Top foreign locations of affiliates owned by ICT Scoreboard Headquarters located in Dublin
			
InBuss 2	Inward ICT business internationalisation	1	**Number of affiliates located in Dublin that are owned by ICT Scoreboard Headquarters located abroad**
			321
			Origins of ICT Scoreboard Headquarters with affiliates located in Dublin
			

5.4.3 ICT Business Networking (NetBuss)

In order to construct an ICT business network and to assess the position of individual regions in it, we rely on the network analysis of the locations of ICT Scoreboard companies and their affiliates. This is done by linking a region where an ICT Scoreboard company is based with a region where it has at least one of its affiliates. Thus, we identify regions as nodes of the network where either an ICT Scoreboard company or affiliate is located. Bilateral relationships (arcs of the network) exist

between regions whenever an ICT Scoreboard company owns an affiliate in a different region.[62] This way we illustrate the destination of business expansion of ICT Scoreboard companies and the location of ICT business activities.[63] This allows us to construct a set of network measures for each region: the analysis of these measures in the case of Darmstadt is presented below.

Analysing this network of ICT business activity allows us to observe the specific position of Darmstadt in it. It also help us to better understand the region's position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Dublin's position in the ICT business network, as observed from the links established by the location and ownership of ICT Scoreboard affiliates,
- The characteristics of the ICT innovation ego network[64] of first degree partners of Dublin,
- The list of the Top 20 partners of Dublin in the ICT business network by the total number of outgoing (an affiliate located in Dublin and owned by an ICT Scoreboard company from a different region) and incoming connections (an affiliate owned by an ICT Scoreboard company located in Dublin and located in a different region).

For the methodology of indicators construction see Section 0.

Dublin's position in the ICT business network

According to **Table 79**, which presents the ranking of Dublin in the ICT business network, the results show that Dublin is among the most central nodes in the ICT business network. In particular:

- Dublin comes 7th out of 485 European regions in the **in-degree** ranking in the ICT business network. This indicator is based on the number of affiliates located in Dublin that belong to any of the ICT Scoreboard companies headquartered outside of Dublin in 2008. In this ranking, Dublin is surpassed by Inner London East, Madrid, Milano, Kreisfreie Stadt Munchen, Groot-Amsterdam and Wien.
- Dublin comes 18th out of 243 European regions in the **out-degree** ranking in the ICT business network. This indicator is based on the number of regions in which ICT Scoreboard companies headquartered in Dublin have their business affiliates in 2008. In this ranking, Dublin is surpassed by Frankfurt am Main, Birkenfeld and Bonn.
- Dublin comes 19th in the **closeness centrality** ranking among the European regions. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Dublin is shown to be a region that is **very close** to other regions of the ICT business network. It is surpassed by Brussels, Milano and Bonn.
- Dublin comes 17th place in the **betweenness ranking** which reflects the position of a node as a hub in the network. Dublin has a strong **intermediary role** between other nodes of

[62] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0. For a full description of the methodology of network analysis and indicators applied, see the EIPE methodology report De Prato, G. & Nepelski, D. 2013a. 'Identifying European ICT Poles of Excellence. The Methodology.' *JRC Scientific and Policy Reports*. Seville: JRC-IPTS.

[63] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's new investment and headquarter is located in the same region.

[64] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

the ICT business network, as compared to the remaining European regions. It is surpassed by such regions as Hochtaunuskreis, Hamburg and Wien.

- Dublin comes 3rd in the **Eigenvector centrality** ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT business network**.** Dublin is **connected with other well-connected nodes**. In this ranking, Dublin is surpassed by only two regions, namely: Inner London East and Groot-Amsterdam.

Table 79: Dublin's ranks in the ICT business network by network measures

Indicator ID	NetRD 1	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	**In-degree in ICT business network**	**Out-degree in ICT business network**	**Closeness centrality in ICT business network**	**Betweenness centrality in ICT business network**	**Eigenvector centrality in ICT business network**
Rank	7	18	19	17	3

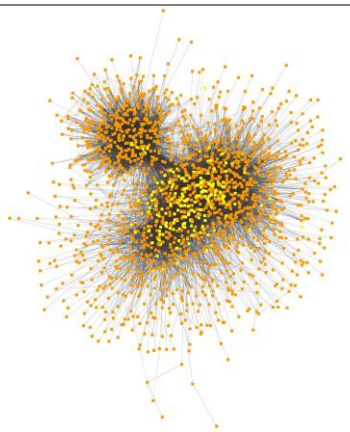
The characteristics of Dublin's ego network

In order to get a deeper insight into the role of Dublin in the ICT business network, we have constructed Dublin's ego network, i.e. a network consisting of Dublin (ego) together with the actors it is connected to (alters) and all the links among those alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Dublin's ego network is a sub-network of the ICT business network and is constructed by taking in account only Dublin's first degree partners, i.e. nodes directly connected with Dublin and the links between them.

The characteristics of this ego network are compared with those of the full ICT business network to see whether there are structural differences between the full network and that of the selected node, Dublin, and its direct partners. This way, we can understand better Dublin's neighbourhood in the ICT business network and, by casting some light on the attributes of its neighbours, see how well it is embedded in the ICT business network.

An illustration of the full ICT business network and its sub-network formed by Dublin's first degree partners (yellow nodes) is given in **Figure 23**. **Table 80** summarises the main measures of the Dublin ego network and compares this network to the full ICT business network.

Figure 23: The ICT business network and the ego network of Dublin



Note: The graph represents the full ICT business network together with the ego network formed by Dublin's first degree partners represented by yellow nodes.

According to **Table 80**, Dublin's ego network includes 130 individual regions connected directly to Dublin, i.e. over 7% of the regions in the full ICT business network. Altogether these regions form over 2,100 linkages, i.e. around 12% of the linkages in the entire network. Thus, the fact that the share of nodes is considerably higher than the share of all connections indicates that an average neighbour of Dublin is significantly better connected than an average node out of the full network.

The density measure, i.e. a ratio of the actual number of links to the number of possible links, shows how well the network is connected. Dublin's ego network shows a **density** of 0.23, as compared to 0.01 for the full ICT business network. Thus, Dublin's ego network is significantly denser than that of the full ICT business network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Dublin's ego network scores 0.57 which is only slightly higher than the score for the full ICT business network. This indicates that, on average, the regions in Dublin's ego network are particularly more clustered than the regions in the full ICT business network. Instead, they are as well connected with all parts of the network as it is the case for the full network. This may also be a result of the fact that Dublin is connected to a significant number of nodes that are either as well or better connected than Dublin.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. Dublin's ego network scores 0.787, as compared to 0.271 for the full ICT business network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in Dublin's ego network than between the nodes in the full network in terms of their position in the network. This might indicate that, for example, in the ego network there are very few nodes with high level of centrality and numerous nodes that play less central roles. The list of the top 20 regions connected to Dublin presented in **Table 81** confirms this view by showing that key hubs of the network as London, Groot Amsterdam, Paris or Tokyo are among Dublin's main partners. Thus, their presence increases the inequality between the nodes significantly.

The **distance**[65] between any two nodes in the Dublin's ego network, measured by the average path length, is 1.8, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network and the presence of nodes that are very well embedded in the network, the distance between any two regions is shorter than it is in the full ICT business network.

The **average number of direct neighbours** of the regions included in the Dublin's ego network is 29, i.e. over 53% more than in the in the full ICT business network, where an average node has only 19 partners. This confirms that the regions in the Dublin's ego network show a higher level of connectedness as compared to the average in the full network.

[65] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Table 80: Characteristics of Dublin's network vs. full ICT business network

Network-Level Measure	Full ICT business network	Dublin's ego network
Node Count	1,840	130
Link Count	18,180	2,155
Density	0.010	0.226
Clustering Coefficient	0.408	0.570
Network centralization	0.271	0.787
Average path length	2.817	1.774
Average number of neighbours	18.641	29.092

Top 20 partners of Dublin in the ICT business network by in- and out-degree

Table 81 lists Dublin's top 20 partners in the ICT business network by two measures in the ICT business network. The first one, i.e. in-degree, tells us about the number of affiliates located in Dublin and owned by ICT Scoreboard companies headquartered in other regions in the world. The second one, i.e. in-degree, refers to the number of affiliates owned by ICT Scoreboard companies headquartered in Dublin and located in other regions around the world.

Regarding the in-degree ranking, the top 20 regions (of 119 in total) in which there is at least one ICT Scoreboard company with affiliates in Dublin, account for 85 affiliates based in this region, i.e. 71% of all ICT Scoreboard affiliates located in Dublin. ICT Scoreboard companies with affiliates in Dublin are from Inner London East, Groot-Amsterdam and Madrid. A few of the regions are from the outside of Europe, i.e. Seoul from South Korea or Bedford and Boston, US.

Concerning the out-degree ranking, the top 20 regions (of 91 in total) in which there is at least one affiliate of an ICT Scoreboard firm headquartered in Dublin, account for altogether 204 affiliates. This represents for 63% of affiliates owned by Dublin ICT Scoreboard companies and located outside of Dublin. The main business destinations of Dublin ICT Scoreboard companies include Schaffhausen, Groot-Amsterdam and San Jose. It is worth noting that 12 out of the 20 regions are in the US.

Thus, though small in absolute numbers, Dublin is an important business destination for ICT Scoreboard companies from around the world. At the same time, ICT Scoreboard companies headquartered in Dublin have the majority of their affiliates outside of Ireland and some of the main locations are in the US. This explains the high score in betweenness and eigenvector centrality informing about the quality of Dublin's connections and, hence, its important role in the ICT business network.

Table 81: Top 20 partners of Dublin in the ICT business network by in- and out-degree

In-degree: Number of affiliates located in Dublin and owned by ICT Scoreboard companies headquartered in ...				Out-degree: Number of affiliates owned by ICT Scoreboard companies headquartered in Dublin and located in ...			
Nr	**Region Code**	**Region name**	**Nr**	**Nr**	**Region Code**	**Region name**	**Nr**
1	UKI12	Inner London East	21	1	CH052	Schaffhausen	29
2	NL326	Groot-Amsterdam	13	2	NL326	Groot-Amsterdam	20
3	ES300	Madrid	8	3	3393	SAN JOSE	20
4	UKJ11	Berkshire	7	4	UKI12	Inner London East	15
5	FR105	Hauts-de-Seine	4	5	3568	SUNNYVALE	15
6	NL411	West-Noord-Brabant	4	6	3055	NORWALK	12
7	DE212	München, Kreisfreie Stadt	4	7	NL414	Zuidoost-Noord-Brabant	10
8	FR101	Paris	3	8	US0608	San Mateo County, CA	10
9	NL310	Utrecht	3	9	2862	MILPITAS	8
10	DK011	Byen København	3	10	2933	MOUNTAIN VIEW	8
11	DE21H	München, Landkreis	3	11	3355	ROUND ROCK	8
12	UKC22	Tyneside	2	12	US0607	San Bernardino County, CA	8
13	KR011	Seoul	2	13	3730	WASHINGTON	6
14	NO011	Oslo	2	14	JPD13	Tokyo	6
15	LU000	Luxembourg	1	15	SE110	Stockholms län	6
16	1658	BEDFORD	1	16	3282	REDMOND	5
17	NL335	Groot-Rijnmond	1	17	3533	STAMFORD	5
18	1738	BOSTON	1	18	BE211	Arr. Antwerpen	5
19	IE013	West	1	19	LU000	Luxembourg (Grand-Duché)	4
20	UKJ13	Buckinghamshire CC	1	20	2868	MINNEAPOLIS	4
Total top 20			**85** (71% in total)	**Total top 20**			**204** (63% in total)
Total			**119**	**Total**			**324**

5.5 Conclusions

This section presents a short summary of the key findings on the ICT activity in Dublin according to the framework depicted in **Figure 2**.

ICT R&D

Concerning the **agglomeration of ICT R&D** activity, one can see that Dublin shows a strong involvement in ICT R&D, at least at academic level. Two Dublin's universities, i.e. University College Dublin and Trinity College Dublin are on the ranking of the QS World University Ranking. Whereas University College Dublin scores high in the citations and academic ranking, the Computer Science faculty of the Trinity College Dublin is among the 20 best faculties in Europe according to the academic ranking. These two universities account also for the entire ICT-related publication output of Dublin. Organisations based in Dublin are rather active in the FP7 programmes. In terms of business R&D, Dublin is a popular location for locating ICT R&D centres of large multinational ICT

companies. According to the gathered data, it hosts research centres belonging to such multinationals as ABB, Alcatel-Lucent, Ericsson or Hewlett-Packard.

Consequently, Dublin exhibits also a high level of **ICT R&D internationalisation** with an R&D activity strongly shaped by large foreign firms. The countries of origin of these companies are mainly the US, Switzerland, France, Japan and Sweden.

Regarding **ICT R&D networking**, Dublin is among the top 30 European nodes of the ICT R&D network. Altogether, it maintains direct connections with nearly half of the European regions that participate to the FP7 programmes. This together with the fact that it is connected with the key players in the network ensures Dublin a rather strong and central position. Dublin seems to be playing a double-featured role in the network: on the one hand, being "only" a mid-size node and, on the other hand, exercising an intermediary role between the main hubs and the less connected nodes. This is not a negligible role in the network, and might be beneficial to Dublin.

ICT Innovation

Concerning **ICT innovation agglomeration** in Dublin, the Irish capital plays it weaker. It is neither strong in terms of investments into intangibles by ICT firms nor in inventive output (as measured by ICT patents). However, it scores remarkably high in the ranking based on the number of venture capital deals, being 5th among the European regions behind such important locations as Inner London East or Cambridgeshire CC. It seems that within the ICT activity, the majority of the newly funded firms develop their activities in the area of business software.

Due to the low level of overall patenting activity, Dublin does also not score particularly high in terms of **ICT innovation internationalisation**. The list of co-inventors' countries includes first the US and the UK, then Japan, Germany and Sweden.

With respect to **ICT innovation networking**, Dublin belongs to the top 60 among EU regions in the number of connections. In addition, it also has a high score due to its intermediary position, which comes from the fact that it maintains strong connections with some distant regions. The list of its co-inventing partners ranges from Silicon Valley to Tokyo, locations which form the core of the network. Thus, by maintaining connections with a number of important nodes and less central nodes Dublin bridges different parts of the network, as it already seems to do with ICT R&D.

ICT Business

Regarding the **ICT Business agglomeration** in Dublin, there are many companies of the ICT R&D Scoreboard that are headquartered in the capital of Ireland. These companies have also a significant number of affiliates located around the world. In addition, Dublin is an important location of business activity of affiliates from ICT R&D Scoreboard companies as well as other ICT firms. This attractiveness has been maintained over the last decade, and Dublin shows a large number of new investments by ICT firms. However, the economic performance of firms in the last few years has shown a significant drop in employment and turnover. Dublin might have an important but somehow turbulent role for ICT business activity in Europe.

As expected, Dublin ranks very high on **ICT business internationalisation** in general and on inward internationalisation in particular (1st place among the European regions): it is an attractive place for foreign ICT businesses. Altogether 321 out of 450 ICT Scoreboard affiliates based in Dublin are of foreign ownership. More than one half belong to the US multinationals. Thus, similarly to Inner London East, though at smaller scale, Dublin is one of the key bridges between Europe and the US.

Concerning **ICT Business networking**, one can observe that Dublin holds a very central and important position in the global ICT Business network. This is due to its attractiveness as a business location. The resulting high number of incoming connections places it among the top regions in Europe. Also ICT Scoreboard companies headquartered in Dublin show a very strong international reach by locating a significant share of their affiliates outside of Ireland. Dublin is also very strongly

connected with the key hubs of the global ICT business network and, hence, is very strongly embedded into this network. The quality of Dublin's business connections makes it one of the key elements of the European ICT landscape.

In conclusion, one can say that to some extent Dublin mimics some characteristics of London. It performs well in terms of ICT R&D – with the ample support of its universities, shows slightly weaker in ICT Innovation but with a strong exception on Venture Capital dynamics, Its main strength is in its ICT Business activity, partly boosted by an impressive attractiveness (Headquarters and affiliates location), and partly by an intrinsic creative dynamic (venture capital activity). All this relies on an excellent positioning in essential neworks: Dublin serves as a bridge between the continent and other ICT-intensive locations, in particular the US.

6. Byen Kobenhavn

This case study presents and analyses the available data gathered throughout the EIPE study about **Byen Kobenhavn** (code DK011). It is a NUTS3 level[66] region of Europe.

Byen Kobenhavn is part of the broader Danish region Hovedstaden (NUTS 2), which consists of the municipalities of Copenhagen and Frederiksberg, the former counties of Copenhagen and Frederiksborg, and the regional municipality of Bornholm. It is a NUTS 2 level region with the 24th highest level GDP per capita in Europe (Eurostat, 2013). The map hereafter shows the localisation (in red) of the Region Hovedstaden (NUTS 2) in Denmark.

Byen Kobenhavn corresponds to the capital city of Copenhagen. Shown in the map below, it is located at the extreme south of Hovedstaden. It has a population of around 1.2 million inhabitants.

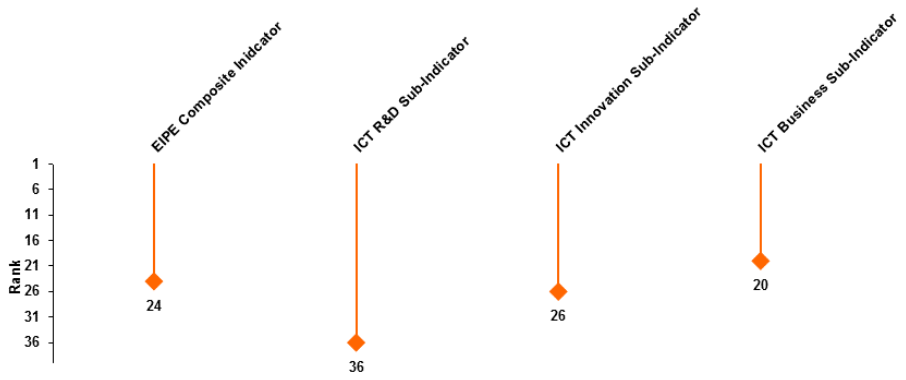
Henceforth, the report often uses the term "Copenhagen" to refer to **Byen Kobenhavn**.

[66] Nomenclature of Territorial Units for Statistics (NUTS). For a list of the European statistical regions see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction.
Source of the map: Wikipedia.

6.1 Byen Kobenhavn in the EIPE ranking

Byen Kobenhavn (DK011) reached the 24th place among 1303 regions in Europe according to the EIPE composite (**Figure 24**). It is surpassed by such regions as Stuttgart, Stadtkreis, Munchen, Landkreis and Heidelberg, Stadtkreis. Hauts-de-Seine, Milano and Berlin (see **Figure 3**). **Figure 24** also shows Byen Kobenhavn's position by individual sub-indicators. According to this information, Byen Kobenhavn comes 36th place in R&D, 26th in innovation and 20th in business activity.

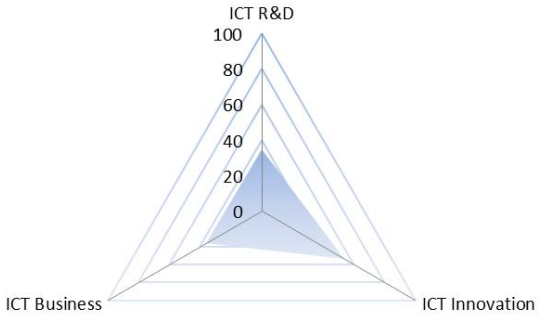
Figure 24: Byen Kobenhavn in the EIPE ranking by EIPE composite indicator, ICT R&D, Innovation and Business sub-indicators



Note: The graph shows the performance of Byen Kobenhavn in the overall EIPE ranking and the ICT R&D, ICT Innovation and ICT Business ranking. The scale represents the rank in comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

Figure 25 compares the performance of Byen Kobenhavn across all three domains, i.e. ICT R&D, ICT Innovation and ICT Business. This figure shows that Byen Kobenhavn performes best in the ICT innovation ranking. On the normalised scale, it scores 50. In the remaining two categories it reached 36 points.

Figure 25: Performance of Byen Kobenhavn in ICT R&D, Innovation and Business



Note: The graph represents the performance of Byen Kobenhavn in the ICT R&D, ICT Innovation and ICT Business rankings. The scale represents normalized scores with maximum 100 and minimum 0. The rankings are based on the analysis of 1303 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

A more detailed picture of Byen Kobenhavn's rankings in each of the 42 indicators, i.e. the Byen Kobenhavn EIPE ID card, is presented **Table 82**. In the following sections, information for each of these indicators is given. Thus, a detailed picture of the ICT activity in Byen Kobenhavn, fully based on the data collected during the study to construct the 42 indicators, is offered.

Table 82: Byen Kobenhavn EIPE ID card

Activity	Characteristic	Name of Indicator	Indicator ID	Rank
R&D	Agglomeration	Universities ranked in the QS University Ranking	AgRD 1	16
		Academic ranking of a Computer Science faculty	AgRD 2	43
		Employer ranking of a Computer Science faculty	AgRD 3	18
		Citations ranking of a Computer Science faculty	AgRD 4	15
		R&D expenditures by ICT firms	AgRD 5	32
		FP7 funding to private organisations	AgRD 6	85
		FP7 participations	AgRD 7	77
		FP7 funding to SMEs	AgRD 8	85
		FP7 participations by SMEs	AgRD 9	77
		Location of ICT R&D centres	AgRD 10	314
		Ownership of ICT R&D centres	AgRD 11	21
		Scientific publications in Computer Science	AgRD 12	35
	Internationalisation	Outward ICT R&D internationalisation	IntRD 1	21
		Inward ICT R&D internationalisation	IntRD 2	260
	Networking	Degree in ICT R&D network	NetRD 1	63
		Closeness centrality in ICT R&D network	NetRD 2	62
		Betweenness centrality in ICT R&D network	NetRD 3	66
		Eigenvector centrality in ICT R&D network	NetRD 4	69
Innovation	Agglomeration	Investment in intangibles by ICT firms	AgIn 1	9
		Venture Capital financing to ICT firms	AgIn 2	4
		ICT patents	AgIn 3	136
	Internationalisation	International co-inventions	IntIn 1	81
	Networking	Degree in ICT innovation network	NetIn 1	88
		Closeness centrality ICT innovation network	NetIn 2	46
		Betweenness centrality ICT innovation network	NetIn 3	71
		Eigenvector centrality ICT innovation network	NetIn 4	197
Business	Agglomeration	Location of ICT Scoreboard Headquarters	AgBuss 1	18
		Ownership of ICT Scoreboard affiliates	AgBuss 2	61
		Location of ICT Scoreboard affiliates	AgBuss 3	23
		Location of ICT firms	AgBuss 4	61
		ICT employment	AgBuss 5	19
		Growth in ICT employment	AgBuss 6	1265
		Turnover by ICT firms	AgBuss 7	15
		Growth in turnover by ICT firms	AgBuss 8	1264
		New business investments in the ICT sector	AgBuss 9	6
	Internationalisation	Outward ICT business internationalisation	IntBuss 1	41
		Inward ICT business internationalisation	IntBuss 2	4
	Networking	In-degree in ICT business network	NetBuss 1	19
		Out-degree in ICT business network	NetBuss 2	49
		Closeness centrality in ICT business network	NetBuss 3	25
		Betweenness centrality in ICT business network	NetBuss 4	43
		Eigenvector centrality in ICT business network	NetBuss 5	73

Note: The table reports the performance of Byen Kobenhavn in each out of the 42 indicators used in the EIPE ranking and grouped around three dimensions, i.e. ICT R&D, ICT Innovation and ICT Business. The scale represents the rank in the comparison with the remaining 1302 European Nuts 3 regions. For further methodological details please refer to Annexes of the current report and to the methodological report documenting the methodology behind the EIPE ranking (De Prato and Nepelski 2013a).

6.2 ICT R&D

This section sheds light on Byen Kobenhavn's performance in ICT R&D activities. It proceeds by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the EIPE Report 2 and presented in **Figure 2**. Detailed background information on the ranking of Byen Kobenhavn by the R&D indicators listed in this region's EIPE ID card can be found in **Table 82**. The next sections analyse the ICT R&D activities in Byen Kobenhavn by looking at their following characteristics:

- ICT R&D Agglomeration (AgRD), i.e. performance of universities and research organisations; private and public ICT R&D expenditures and the location of ICT R&D centres (Section 0),
- ICT R&D Internationalisation (IntRD), i.e. the number of ICT R&D centres located outside Denmark that are owned by companies with headquarters located in Byen Kobenhavn (outward internationalisation) and the number of ICT R&D centres located in Byen Kobenhavn that are owned by foreign companies (inward internationalisation) (Section 0),
- ICT R&D Networking (NetRD), i.e. linkages formed by research organizations located in Byen Kobenhavn when they participate in joint FP7 programmes with organizations located in other regions (Section 0).

6.2.1 ICT R&D Agglomeration (AgRD)

The analysis of the ICT R&D Agglomeration in Byen Kobenhavn starts by providing a snapshot on the universities and the bibliometric output of organizations located in the region (see **Table 83**). This information is based on the QS World University Rankings (reference year 2008) and the Thomson Reuters Web of Knowledge (reference years 2000-2012). For the methodology of indicators construction see Section 0.

Byen Kobenhavn has two universities included in the QS ranking, i.e. University of Copenhagen and Technical University of Denmark. Taking into account its share in the total EU population, Byen Kobenhavn ranks 16th for universities among all European regions.

A closer look at the specific performance of individual computer science faculties shows that, out of the two universities, the University of Copenhagen is leading in all the individual rankings. Among the best computer science faculties in Europe, it ranks between the 15th place in the citations ranking and 43rd in the academic ranking

As regards the indicator "scientific publications in Computer Science", the research organisations based in Byen Kobenhavn produced over 1157 publications (1% of EU total) between 2000 and 2012 (as registered by Thomson Reuters). Considering Byen Kobenhavn's share in the EU population, this results in a 35th place in this ranking. Taken together, Technical University of Denmark and University of Copenhagen account for all publications produced in the region.

Table 83: ICT R&D Agglomeration: Universities & bibliometrics

Indicator ID	Name of indicator	Rank	Byen Kobenhavn universities in QS university ranking	
AgRD 1	**Universities ranked in the QS University Ranking**	16	3. University of Copenhagen 4. Technical University of Denmark	
			The best performing Computer Science faculty of a Byen Kobenhavn university according to the …	
AgRD 2	**Academic ranking of a Computer Science faculty**	43	University of Copenhagen	
AgRD 3	**Employer ranking of a Computer Science faculty**	18	University of Copenhagen	
AgRD 4	**Citations ranking of a Computer Science faculty**	15	University of Copenhagen	
AgRD 12	**Scientific publications in Computer Science**	35	**Total number of publications**	**% in EU total**
			1,157	1%
			Research organizations with the highest number of publications, number of publications in brackets	
			5. Technical University of Denmark (656) 6. University of Copenhagen (501)	

Regarding public ICT R&D expenditures, they are proxied here by FP7 funding data attributed to research projects in which private and/or public organizations, based in Byen Kobenhavn participated in the time period between 2007 and 2011 (see **Table 84**).

Given its share in the total EU population, Byen Kobenhavn ranks 85th in the EU as regards FP7 funding to organization. Between 2007 and 2011, organizations based in Byen Kobenhavn received 41 M Euro for FP7 projects. This represents 0.35% of the total EU ICT FP7 funding. The five organizations that received the highest amount of funding were four higher education institutions, Danmarks Tekniske Universiteit, IT University of Copenhagen, University of Copenhagen, Copenhagen Business School, and one private company, i.e. Comfort Consulting KFT.

Byen Kobenhavn also ranks 77th among all European regions (again taking into account its share in the total EU population) with respect to the number of participations in FP7 project. Between 2007 and 2011, organizations based in Byen Kobenhavn participated in 108 FP7 projects. This represents 0.36% of all FP7 projects in this period. Organizations with the highest participation rate accounted for over 40% of all the projects granted to organizations based in Byen Kobenhavn.

Byen Kobenhavn, given its share in the total EU population, London ranks 85th among all the European regions for the amount of FP7 funding granted to SMEs. Between 2007 and 2011, SMEs based in Byen Kobenhavn received 11 M Euro for FP7 projects. This represents 0.45% of the total EU ICT FP7 funding to SMEs. A different pattern emerges when we look at the number of participations to FP7 project by SMEs based in Byen Kobenhavn. Here, one can see that, given its share in the total EU population, Byen Kobenhavn ranks 77th among all the European regions. Byen Kobenhavn-based SMEs were involved in 30 FP7 projects, i.e. 0.45% of FP7 projects to which SMEs participated Europe-wide.

Given the overall share of participations in FP7 funding by organizations based in Byen Kobenhavn, i.e. 0.35% in the EU total, SMEs based in this region show an average participation rate to the FP7 projects, i.e. 0.45% of the EU total.

Table 84: ICT R&D Agglomeration: FP7 funding and participation

Indicator ID	Name of indicator	Rank		
AgRD 6	FP7 funding	85	**Total amount of funding (in M of Euro)**	**% in EU total**
			41	0.35%
			Research organizations based in Byen Kobenhavn with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			1. DANMARKS TEKNISKE UNIVERSITET (5) 2. IT UNIVERSITY OF COPENHAGEN (4) 3. UNIVERSITY OF COPENHAGEN (3) 4. COPENHAGEN BUSINESS SCHOOL (2) 5. COMFORT CONSULTING KFT(2)	
AgRD 7	FP7 participations	77	**Number of participations**	**% in EU total**
			108	0.36%
			Research organizations based in Byen Kobenhavn with the highest number of participations in FP7 projects, number of participations in brackets	
			1. DANMARKS TEKNISKE UNIVERSITET (16) 2. IT UNIVERSITY OF COPENHAGEN (9) 3. UNIVERSITY OF COPENHAGEN (9) 4. DEPARTMENT OF COMMUNICATIONS OPTICS AND MATERIALS (COM) TECHNICAL UNIVERSITY OF DENMARK (6) 5. IN-JET APS (5)	
AgRD 8	FP7 funding to SMEs	85	**Total amount of funding (in M of Euro)**	**% in EU total**
			11	0.45%
			SMEs based in Byen Kobenhavn with the highest amount of funding, amount per organization in brackets (in M of Euro)	
			1. IN-JET APS (1.5) 2. NANGATE A/S (0.8) 3. MOBI SOLUTIONS OÜ (0.8)	
AgRD 9	FP7 participations by SMEs	77	**Number of participations**	**% in EU total**
			30	0.41%
			SMEs based in Byen Kobenhavn with the highest number of participations in FP7 projects, number of participations in brackets	
			1. IN-JET APS (5) 2. TEAMCAST (2) 3. NETMINERS APS (1) 4. NANGATE A/S (1) 5. MOBILE INTERNET TECHNOLOGY A/S (1)	

Information on average annual expenditures on R&D by ICT firms and on the location and ownership of ICT R&D centres is used to provide further details on ICT R&D agglomeration (see **Table 85**). Data on the average annual amount spent on R&D in the ICT sector for the period 2005-2011 originate from the ORBIS database developed by Bureau Van Dijk. Data on the location and ownership of ICT R&D centres[67] is for 2012 and stems from the Design Activity Tool developed by IHS iSuppli, an industry consultancy which specialises in observing the ICT sector.

Byen Kobenhavn, given its share in the total EU population, ranks 32nd among the European regions with respect to average annual expenditures on R&D by ICT firms,. In the period between 2005 and 2011, ICT firms based in Byen Kobenhavn spent on average 0.05 M Euro annually on R&D. This represents 0.2% of the total EU R&D expenditures by ICT firms. ICT firms with the highest R&D budget were, for example, Thrane & Thrane A/S, TDC A/S and SIMCORP A/S.

Considering R&D centres, Byen Kobenhavn does not host companies considered as *major semiconductor influencers* (IHS iSuppli definition) nor their R&D facilities. Hence, Byen Kobenhavn ranks 314th and 21st in these two rankings, sharing the position with the remaining European regions where there are neither companies considered as major semiconductor influencer nor their R&D centres.

Table 85: ICT R&D Agglomeration: R&D expenditures and R&D centres

Indicator ID	Name of indicator	Rank		
AgRD 5	R&D expenditures by ICT firms	32	**Total amount of funding (in M of Euro)**	**% in EU total**
			0.049	0.2%
			R&D investors based in Byen Kobenhavn with the highest amount of R&D expenditures	
			1. THRANE & THRANE A/S 2. TDC A/S 3. SIMCORP A/S 4. NETBOOSTER A/S 5. NETOP SOLUTIONS A/S	
AgRD 10	Location of ICT R&D centres	314	**Number of R&D centres located in Byen Kobenhavn**	**% in EU total**
			n.a.	n.a.
			Firms with the highest number of R&D centres located in Byen Kobenhavn	
			n.a.	
AgRD 11	Ownership of ICT R&D	21	**Number of R&D centres owned by firms based in Byen Kobenhavn**	**% in EU total**
			n.a.	n.a.
			Firms based in Byen Kobenhavn with the highest number of R&D centres owned worldwide	
			n.a.	

6.2.2 ICT R&D Internationalisation (IntRD)

The analysis of ICT R&D Internationalisation in Byen Kobenhavn is based on data on the location and ownership of R&D centres for 2012 provided by the Design Activity Tool (published by HIS

[67] Those R&D Centres belong to the firms considered as major semiconductors influencers by HIS iSuppli.

iSuppli, an industry consultancy which specialises in the ICT sector). The information on ICT R&D internationalisation in Byen Kobenhavn is presented in **Table 86**.

As already noted in the previous section (see **Table 85**), there are neither major semiconductor influencers (IHS definition) nor their R&D facilities in Byen Kobenhavn. Hence, this region ranks 21st and 260th in the outward and inward ICT internationalisation, sharing these positions with other European regions where there are no such companies nor their R&D centres.

Table 86: Outward and inward R&D internationalisation

Indicator ID	Name of indicator	Rank	
InRD 1	Outward ICT R&D internationalisation	21	**Number of ICT R&D centres located outside of Denmark that are owned by companies' headquarters located in Byen Kobenhavn**
			n.a.
			Top locations of R&D centres owned by firms from Byen Kobenhavn
			n.a.
InRD 2	Inward ICT R&D internationalisation	260	**Number of ICT R&D centres located in Byen Kobenhavn that are owned by foreign companies**
			n.a.
			Origins of companies with R&D centres located in Byen Kobenhavn
			n.a.

6.2.3 ICT R&D Networking (NetRD)

In order to construct an ICT R&D network and to assess the position of individual regions in it, we rely on data on participation in the ICT part of the FP7 programme. All NUTS3 regions where FP7 ICT R&D programme partners are located are identified as nodes of the network. Bilateral relationships (arcs of the network) between regions exist whenever an organisation from one region participates in a FP7 ICT R&D programme together with an organization from a different region.[68] This allows us to construct a set of network measures for each region and the analysis of these measures for Byen Kobenhavn's is presented below.

Analysing the network of collaborations in the FP7 ICT R&D programme allows us to see Byen Kobenhavn's specific position in the EIPE ranking and better understand its high position and the role it plays in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Byen Kobenhavn's position in the ICT R&D network, as observed from the collaborative links established by the organisations located in Byen Kobenhavn with organisations located in other European regions, and the characteristics of these links,

[68] For more details on the methodology of constructing a network and its application to ICT R&D, see Section 0.

- The characteristics of Byen Kobenhavn ego network[69] formed by its first degree partners in the ICT R&D network,
- Byen Kobenhavn's list of Top 20 partners in the ICT R&D network and the total number of joint projects with each.

For the methodology for indicators construction see Section 0.

Byen Kobenhavn's position in the ICT R&D network

Table 87, which presents Byen Kobenhavn's ranking in the ICT R&D network confirms the rather strong and central role Byen Kobenhavn plays in the ICT R&D network, but with the following nuances:

Byen Kobenhavn comes 63rd out of 761 regions in the degree ranking. This indicator is based on the number of collaborations a given region maintains with other regions in the ICT R&D network. Research organizations based in Byen Kobenhavn participated in 667 FP7 projects between 2007 and 2012. Byen Kobenhavn is directly **connected with 212 regions** (28% of the all the regions) that participate in the ICT R&D network. This is an average high score, considering the overall number of the nodes in the network. In the degree ranking, Byen Kobenhavn is surpassed, by for example, Arr. Antwerpen (rank 60), Outer London (rank 61) and Pirkanmaa (rank 62) and immediately followed by Nordjylland (rank 63), Surrey (rank 63) and Haute-Garonne (rank 64).

- Byen Kobenhavn also comes 62nd in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance from other nodes in the network. It shows that Byen Kobenhavn is **a region close** to the remaining 760 regions in the ICT R&D network. Again, the regions that immediately proceed and follow Byen Kobenhavn in the closeness centrality ranking are the same ones as in the degree ranking.
- Byen Kobenhavn comes 66th in the betweenness ranking which reflects the position of a node as a hub in the network. The relative difference between the place in the betweenness ranking and the remaining rankings shows that Byen Kobenhavn is playing some role as **an intermediary** between other nodes of the ICT R&D network.
- Byen Kobenhavn comes 69th in the Eigenvector centrality ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT R&D network. Thus, despite not being one of the hubs of the network, Byen Kobenhavn's **neighbours seem to be well-connected nodes**.

Table 87: Byen Kobenhavn's ranks in the ICT R&D network by network measures

Indicator ID	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	Degree in ICT R&D network	Closeness centrality in ICT R&D network	Betweenness centrality in ICT R&D network	Eigenvector centrality in ICT R&D network
Rank	63	62	66	69

The characteristics of Byen Kobenhavn's ego network

In order to get a deeper insight into the role of Byen Kobenhavn in the ICT R&D network, we have built its *ego network.* Byen Kobenhavn's ego network is a sub-network of the entire ICT R&D

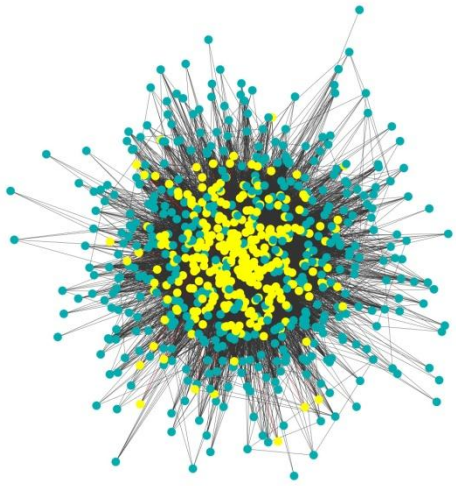
[69] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

network, constructed by taking in account only Byen Kobenhavn's first degree partners (or alters), i.e. nodes directly connected with Byen Kobenhavn and the links among them.[70]

The characteristics of this ego network are then compared with those of the full ICT R&D network to see whether there are some structural differences between the full network and the ego network of the selected node, here Byen Kobenhavn. This way, we can understand better Byen Kobenhavn's neighbourhood in the ICT R&D network and, by casting some light on the attributes of its neighbours, to see how well it is embedded in the ICT R&D network.

A graphical illustration of the full network and its ego network formed by Byen Kobenhavn's first degree partners (yellow nodes) is given in **Figure 26**. **Table 88** summarises the main measures of the Byen Kobenhavn sub-network and compares it to the full ICT R&D network.

Figure 26: The ICT R&D network and the ego network of Byen Kobenhavn



Note: The graph represents the full ICT R&D network together with the ego network formed by Byen Kobenhavn's first degree partners represented by yellow nodes.

According to **Table 88**, Byen Kobenhavn's ego network includes 213 individual regions, i.e. 28% of the regions in the full network. Altogether these regions form over 10,000 linkages, i.e. 37% of the linkages formed in the entire network.

Byen Kobenhavn's ego network shows a **density**, i.e. a ratio of the actual number of links to the number of possible links of 0.451, as compared to 0.095 for the full sample. This indicates that the general **connectivity** of Byen Kobenhavn's ego network is significantly higher than the value for the full network. In other words, the regions belonging to the Byen Kobenhavn's sub-network are better connected among each other, than all the regions participating in the FP7 programme.

The **clustering** coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. The score of Byen Kobenhavn's ego network is 0.772 and is slightly higher than that of the full network. This indicates that the regions present in the Byen Kobenhavn's ego network are more clustered than the regions in the full ICT R&D network. Thus, due to a high value of the clustering coefficient, the sub-network nodes form clusters of tightly connected sub-groups. These sub-groups are linked through cities playing a role of intermediaries, i.e. hubs of the network.

[70] Ego networks are also known as the neighbourhood networks or first degree neighbourhoods of ego Everett, M. & Borgatti, S. 2005. 'Ego network betweenness.' *Social Networks,* 27:1, 31-38.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, shows how equal nodes are in terms of their positions in the network. Byen Kobenhavn's ego network scores 0.56, as compared to 0.64 for the full network. This suggests that the most central node in Byen Kobenhavn's ego network has a lower level of centrality than its equivalent node in the full network. Thus, in relative terms, there is a smaller variation in the nodes' positions in the network, which indicates that this network is composed of nodes which are quite similar with respect to their network position and characteristics.

Regarding the distance between the nodes, measured by the average number of steps along the shortest paths for all possible pairs of network, the **average path length** between any two nodes in Byen Kobenhavn's ego network is 1.5, as compared to nearly 2 in the full network. Thus, due to a denser web of connections between the nodes in the ego network, the distance between any two nodes is shorter as compared to the full network.

The **average number of direct neighbours** of the regions in the Byen Kobenhavn's ego network is 96, i.e. over 30% more than it is in the full ICT R&D network, where an average node has only 72 partners. Thus, Byen Kobenhavn's ego network is composed of nodes with higher level of connectedness as compared to the average in the full network.

Table 88: Characteristics of Byen Kobenhavn's ego network vs. full ICT R&D network

Network-Level Measure	Full Network	Byen Kobenhavn
Node Count	761	213
Link Count	27,490	10,174
Density	0.095	0.451
Clustering Coefficient	0.755	0.772
Network centralization	0.638	0.555
Average path length	1.980	1.549
Average number of neighbours	72.247	95

Byen Kobenhavn's Top partners in the ICT R&D network

Table 89 gives the list of Byen Kobenhavn's top 20 partners in the ICT R&D network and the number of joint projects carried out with each. In addition, the rankings for each partner in the four network measures are given.

Of the 212 partners with which Byen Kobenhavn maintains direct connections in the ICT R&D network, relationships with **the top 20 partners account for over 41%** of the 277 projects in which organisations located in Byen Kobenhavn were involved. This provides evidence for the existence of strong agglomeration forces in the shaping of the ICT R&D landscape

Regarding the network characteristics of Byen Kobenhavn's top 20 partners, the majority of collaborations are conducted with regions which themselves play a very strong and central role in the network. For example, the major partners of Byen Kobenhavn in terms of the number of joint projects are Paris, Munchen and Madrid, all three being keys node in the ICT R&D network by the network measures reported in Table 89. Again, all this provides additional evidence of the strong agglomeration forces that are present in the shaping of the ICT R&D landscape. However, there are some deviations from this rule. The presence of two Swedish regions, i.e. Stockholms lan and Vastra Gotalands lan, in the top ten indicates that there other forces that favour R&D collaboration. In this case, it is either geographical proximity or technological complementarity that drives the collaboration between the regions, or a mix of both.

Table 89: Top 20 partners of Byen Kobenhavn in the ICT R&D network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint projects**	**Share in total**	**Degree in ICT R&D network**	**Closeness centrality in ICT R&D network**	**Betweennes s centrality in ICT R&D network**	**Eigenvector centrality in ICT R&D network**
1	FR101	Paris	25	3.7%	2	2	2	2
2	DE212	Kreisfreie Stadt Munchen	24	3.6%	1	1	1	1
3	ES300	Madrid	19	2.8%	3	3	4	3
4	UKI12	Inner London East	18	2.7%	4	4	7	5
5	GR300	Attiki	16	2.4%	4	4	6	4
6	SE110	Stockholms lan	16	2.4%	15	15	12	14
7	AT130	Wien	14	2.1%	11	11	11	10
8	SE232	Vastra Gotalands lan	14	2.1%	35	35	38	33
9	BE100	Arr. de Bruxelles-Capitale	13	1.9%	10	10	10	11
10	ITC45	Milano	13	1.9%	6	6	5	6
11	ITE43	Roma	13	1.9%	7	7	3	7
12	FI181	Uusimaa	12	1.8%	9	9	9	9
13	NL414	Zuidoost-Noord-Brabant	12	1.8%	17	17	22	17
14	ITC11	Torino	11	1.6%	16	16	16	18
15	BE242	Arr. Leuven	10	1.5%	13	13	13	13
16	FR105	Hauts-de-Seine	10	1.5%	20	20	25	16
17	HU101	Budapest	10	1.5%	19	19	19	20
18	ES523	Valencia / Valencia	9	1.3%	28	28	30	30
19	PT171	Grande Lisboa	9	1.3%	23	23	24	24
20	UKG13	Warwickshire	9	1.3%	25	25	29	28
Total Top 20			**277**	**41.5%**				
Total			**667**	**100%**				

6.3 ICT innovation

This section sheds light on Byen Kobenhavn's performance in the ICT business activities by making use of the information collected within the EIPE project. This analysis follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. Detailed background information on the region's rankings for the ICT business indicators is presented (**Table 82**). (Byen Kobenhavn EIPE ID card). ICT business activities are analysed by looking at the following characteristics:

- ICT Innovation Agglomeration (AgIn), i.e. investment in intangibles by ICT firms, venture capital financing to ICT firms and ICT patents (Section 0),
- ICT Innovation Internationalisation (IntIn), i.e. the number of ICT inventions developed by inventors located in Byen Kobenhavn and outside Denmark (Section 0),
- ICT Innovation Networking (NetIn) i.e. the place of Byen Kobenhavn in the ICT innovation network formed by co-inventions jointly developed by inventors located in regions around the world (Section 0).

6.3.1 ICT Innovation Agglomeration (AgIn)

The analysis of the ICT Innovation Agglomeration in Byen Kobenhavn starts with providing information on the amount of investment in intangibles by ICT firms, venture capital funding to ICT firms and the number of ICT patents (see **Table 90**). This data comes from the company-level database ORBIS by Bureau Van Dijk (reference years from 2005 to 2012), Venture Source by Dow Jones (reference years from 2000 to 2012) and REGPAT by OECD-EPO (reference years from 2000 to 2012) respectively. For the methodology for indicators construction see Section 0.

Byen Kobenhavn ,given its share in the total EU population, ranks 9th among the European regions with respect to average annual ICT firms' investment in intangibles. According to the company-level database ORBIS by Bureau Van Dijk, in the period 2005-2011, ICT firms based in Byen Kobenhavn spent on average 4.66 M Euro annually on intangibles. Among ICT firms based in Byen Kobenhavn which invested most in intangibles were, for example, TDC, Thrane&Thrane and Netbooster.

Regarding the number of venture capital deals to ICT firms, Byen Kobenhavn ranks 4th among all the EU regions. Between 2000 and 2012, there were 561 VC deals were made with ICT firms based in Byen Kobenhavn. Funded companies include, among others, Ascio Technologies, a provider of Domain Portfolio Management services; CyberCity, a company engaging in the development, management, and sale of broadband solutions and network-based security; or Rovsing Dynamics, a provider of monitoring solutions of machinery health and predictive maintenance information for oil and gas, maritime, and power generation industries.

ICT innovation output is measured by the number of ICT patents. Organisations based in Byen Kobenhavn produced 367 (0.28% of EU total) patented ICT inventions in the period between 2000 and 2012. This figure and Byen Kobenhavn's share in the EU population puts the region in 136th place in this ranking.

Table 90: ICT Innovation agglomeration in Byen Kobenhavn

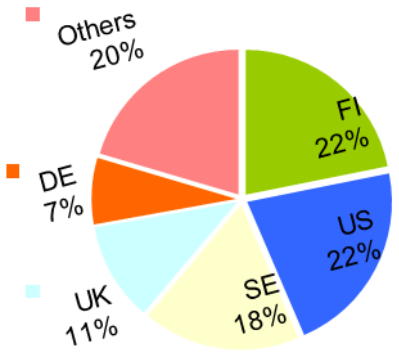
Indicator ID	Name of indicator	Rank		
AgIn 1	Investment in intangibles by ICT firms	9	**Total amount of (in M of Euro)**	**% in EU total**
			4.66	1.13%
			Top investors in intangibles by firms based in Byen Kobenhavn	
			1. TDC A/S 2. THRANE & THRANE A/S 3. NETBOOSTER A/S 4. NETOP SOLUTIONS A/S 5. SIMCORP A/S	
AgIn 2	Venture Capital financing to ICT firms	4	**Number of VC financial deals to firms based in Byen Kobenhavn**	**% in EU total**
			561	2%
			Organizations with the highest amount of VC funding	
			1. Ascio Technologies 2. Alta 3. CyberCity 4. Rovsing Dynamics A/S 5. Catalog International	
AgIn 3	ICT patents	136	**Total number of ICT patents**	**% in EU total**
			367	0.28%

6.3.2 ICT Innovation Internationalisation (IntIn)

The analysis of ICT Innovation internationalisation in Byen Kobenhavn is based on the data on ICT international co-inventions, i.e. the number of patents with an inventor residing in Byen Kobenhavn and at least one inventor residing outside of Denmark. The data originates from REGPAT (source: OECD-EPO) and covers the period from 2000 to 2012. For the methodology of indicator construction see Section 0.

According to the information presented in **Table 91**, among the total 378 ICT inventions that included Byen Kobenhavn-based inventors, 100 were an output of international collaboration involving residents from outside of Denmark. This gives Byen Kobenhavn the 81st place in the current ranking. The main partners in ICT co-inventing activity of Byen Kobenhavn-based inventors were from Finland, the US, Sweden, the UK and Germany.

Table 91: ICT innovation internationalisation of Byen Kobenhavn

Indicator ID	Name of indicator	Rank	
IntIn 1	International co-inventions	81	**Number of international ICT co-inventions**
			232
			Top countries by the number of co-inventions between inventors located in Byen Kobenhavn and ...
			

6.3.3 ICT Innovation Networking (NetIn)

In order to construct an ICT innovation network and to assess the position of individual regions in it, we rely on the network analysis of the locations of inventors residing in different regions of the world (3646 regions in total) and jointly developing ICT inventions for which a patent application has been introduced (period 2000-2009). The relationship between two different locations can be described as the total sum of co-inventions developed by inventors residing in these two regions (Guellec and Van Pottelsberghe de la Potterie 2001).

We identify all regions where inventors are located as nodes of the network. Bilateral relationships (arcs of the network) exist between regions whenever an inventor from one region co-developed an invention with an inventor based in a different region.[71] These definitions allow us to construct a set of network measures for each region: the analysis of those measures in the case of Byen Kobenhavn is presented below.

Analysing this network of inventor collaborations in technology development allows us to observe the specific position of Byen Kobenhavn in the ICT innovation network, as compared to other European regions. It also enables us to better understand its position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Byen Kobenhavn 's position in the ICT innovation network, as observed from the collaborative links established by inventors located in Byen Kobenhavn with inventors located in other regions around the world, and the characteristics of these links,

[71] For more details on the methodology of constructing a network and its application to ICT innovation, see Section 0.

- The characteristics of the ICT innovation ego network[72] of first degree partners of Byen Kobenhavn ,
- Byen Kobenhavn's top 20 partners in the ICT innovation network and the number of inventions patented jointly with each.

For the methodology of indicators construction see Section 0.

Byen Kobenhavn's position in the ICT innovation network

Table 92, which presents Byen Kobenhavn's ranking in the ICT innovation network shows that Byen Kobenhavn plays a rather central role in the ICT innovation network, but with some nuances. In particular:

- Byen Kobenhavn comes 63rd out of 1189 European regions (out of 3,656 in total worldwide) present in the ICT innovation network by the degree indicator. This is based on the number of collaborations a given region maintains with other regions in the ICT innovation network with altogether 3646 regions worldwide through joint co-inventions in the period between 2000 and 2009. Byen Kobenhavn is directly **connected with 208 regions** (6% of all the regions) that participate in ICT innovation network.
- Byen Kobenhavn also comes 62nd in the closeness centrality ranking. This ranking tells us how well connected a region is in terms of distance to other nodes in the network. Byen Kobenhavn is shown to be **a region close** to the remaining regions of the ICT innovation network.
- Byen Kobenhavn comes 66th in the betweenness ranking, a ranking that reflects the position of a node as a hub in the network. The relative difference between the place in the betweenness ranking and the remaining rankings shows that Byen Kobenhavn is somehow relevant as **an intermediary** between other nodes of the ICT innovation network.
- Byen Kobenhavn comes 69h in the Eigenvector centrality ranking, reflecting the importance of Byen Kobenhavn based on the role of its neighbours in the ICT innovation network. Thus, considering the degree ranking, **neighbours of Byen Kobenhavn seem to be worse-connected than Byen Kobenhavn itself**.

Table 92: Byen Kobenhavn's rankings in the ICT innovation network by network measures

Indicator ID	NetIn 1	NetIn 2	NetIn 3	NetIn 4
Indicator Name	Degree in ICT innovation network	Closeness centrality in ICT innovation network	Betweenness centrality in ICT innovation network	Eigenvector centrality in ICT innovation network
Rank	63	62	66	69

The characteristics of Byen Kobenhavn's ego network

In order to get a deeper insight into the role of Byen Kobenhavn in the ICT innovation network, we have constructed its ego network, i.e. a network consisting of Byen Kobenhavn (ego), the actors it is connected to (alters) and all the links between these alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus,

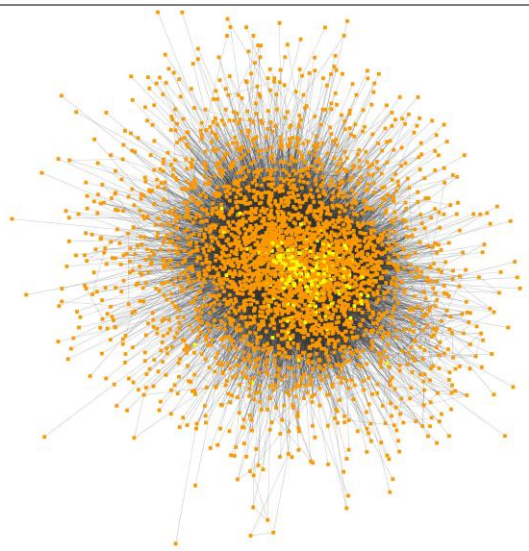
[72] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

Byen Kobenhavn ego network is constructed by taking into account only Byen Kobenhavn first degree partners, i.e. nodes directly connected with Byen Kobenhavn and the links between them.

The characteristics of this ego network are compared with those of the full ICT innovation network to see whether there are some structural differences between the full network and the one of the selected node, Byen Kobenhavn, and its direct partners. This comparison will help us to understand better Byen Kobenhavn position in the ICT innovation network. In addition, by casting some light on its neighbours' attributes, it will allow us to see how well the region's neighbourhood network is embedded in the ICT innovation network.

An illustration of the full ICT innovation network and its sub-network formed by Byen Kobenhavn first degree partners (yellow nodes) is given in **Figure 27**. Table 73 summarises the main measures of the Byen Kobenhavn ego network and compares it to the full ICT innovation network.

Figure 27: The ICT innovation network and the ego network of Byen Kobenhavn



Note: The graph represents the full ICT R&D network together with the ego network formed by Byen Kobenhavn's first degree partners represented by yellow nodes.

According to Table 73, Byen Kobenhavn's ego network includes 208 individual regions connected directly to Byen Kobenhavn, i.e. 6% of the regions in the full ICT innovation network. Altogether these regions form over 6,300 linkages, i.e. 7% of the linkages present in the entire network.

Network density, i.e. a ratio of the actual number of links to the number of possible links, shows how well the network is connected. Byen Kobenhavn's ego network has **density** of 0.31, as compared to 0.014 for the full ICT innovation network. Thus, the ego network is significantly denser than that of the full ICT innovation network.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Byen Kobenhavn's ego network scores 0.65 which is higher than that of the full ICT innovation network. This indicates that the regions present in Byen Kobenhavn's ego network are clustered into more tightly connected groups as compared to the other regions present in the full ICT innovation network.

The **network centralization** level of a network measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. For the Byen Kobenhavn's ego network, it scores 0.69, as compared to 0.3 for the full ICT innovation network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in the ego network than between the nodes in the full network in terms of their

position in the network. This indicates that there are few nodes with very central position in the network and numerous nodes that play less central roles. This is confirmed by the composition of Byen Kobenhavn's top 20 partners in **Table 94**, which include both peripheral Danish regions as well as Silicon Valley and Asian nodes.

The **distance**[73] between any two nodes in the Byen Kobenhavn's ego network, measured by the average path length, is 1.7, as compared to 2.7 in the full network. Thus, due to a denser web of connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT innovation network.

The **average number of direct neighbours** of the regions included in the Byen Kobenhavn's ego network is 64, i.e. over 25% more than in the in the full ICT innovation network, where an average node has only 52 partners. This confirms that the regions in the Byen Kobenhavn's ego network show a higher level of connectedness than the average in the full network.

Table 93: Characteristics of Byen Kobenhavn ego network vs. full ICT innovation network

Network-Level Measure	Full Network	Byen Kobenhavn
Node Count	3,646	208
Link Count	94,689	6,734
Density	0.014	0.313
Clustering Coefficient	0.499	0.654
Network centralization	0.320	0.694
Average path length	2.676	1.687
Average number of neighbours	51.941	64.75

Top 20 partners of Byen Kobenhavn in the ICT innovation network

Table 94 lists Byen Kobenhavn's top 20 partners in the ICT innovation network, showing the number of joint patents. In addition, the four network measures are ranked for each partner. Because the list of partners also includes non-EU regions, the ranks of the neighbours are given for the whole network, i.e. including non-EU regions. Hence, this way, the ranks presented here are not comparable with the ranking of the EU regions.

Of the 249 partners with which Byen Kobenhavn maintains direct connections in the ICT innovation network, the relationships with **the top 20 partners account for 85%** of all the co-patents between innovators located in Byen Kobenhavn and other regions. This provides evidence for the existence of strong agglomeration forces that are present in the shaping of the ICT R&D landscape.

Regarding Byen Kobenhavn's top 20 partners, it can be seen that that the majority of the inventors who work together with Byen Kobenhavn's inventors are located in regions that are located near Byen Kobenhavn or in Denmark. For example, the major partners of in terms of the number of joint patents include Københavns omegn (DK012), Nordsjælland (DK013), Østsjælland (DK021). However, what is quite striking is that 13 in the top 20 are regions from the outside of Denmark and Europe. The first three largest non-Danish region are Scandinavian regions such as is Uusimaa (FI181), Skåne län (SE224), Stockholms län (SE110). The main non-European regions include three Californian regions Los Angeles (US06037), Santa Clara (US06085) and San Diego (US06073) and Beijing (CN01). Thus, this shows that the role of Byen Kobenhavn as an inter-regional hub in the ICT innovation network is very well pronounced clearly justified.

[73] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

Table 94: Byen Kobenhavn's Top 20 partners in the ICT innovation network

					Rank by			
Nr	**Nuts 3 code**	**Name of region**	**Nr of joint patents**	**Share in total**	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweennes s centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
1	DK012	Københavns omegn	35.6	29.6%	273	246	261	967
2	DK013	Nordsjælland	34.2	28.5%	277	247	283	979
3	DK021	Østsjælland	7.7	6.5%	752	528	828	1827
4	DK022	Vest- og Sydsjælland	3.6	3.0%	1160	901	697	1842
5	FI181	Uusimaa	3.5	2.9%	93	106	67	316
6	SE224	Skåne län	3.4	2.8%	166	156	166	242
7	SE110	Stockholms län	2.0	1.7%	36	50	20	124
8	FI197	Pirkanmaa	1.6	1.4%	355	318	253	505
9	DK050	Nordjylland	1.5	1.3%	666	615	810	1156
10	DK042	Østjylland	1.5	1.2%	687	577	854	935
11	FI1A2	Pohjois-Pohjanmaa	1.2	1.0%	456	360	386	704
12	US06037	Los Angeles County	1.2	1.0%	7	17	5	85
13	IS011	Höfuðborgarsvæði	0.9	0.8%	953	681	463	1609
14	FI183	Varsinais-Suomi	0.9	0.7%	501	395	623	768
15	US06085	Santa Clara County	0.8	0.7%	1	11	1	16
16	DK041	Vestjylland	0.6	0.5%	1351	1112	1750	2030
17	CN01	Beijing	0.6	0.5%	235	153	175	2204
18	US06073	San Diego County, CA	0.5	0.4%	4	14	4	55
19	UKJ11	Berkshire	0.5	0.4%	87	95	134	177
20	UKI12	Inner London East	0.5	0.4%	128	137	247	193
Total Top 20			**102.4**	**85.3%**				
Total nr of joint patents			**120.1**	**100%**				

6.4 ICT Business

This section sheds light on Byen Kobenhavn's performance in the ICT business activities by making use of the information collected in the EIPE project. This analysis follows the empirical framework defined in the second EIPE Report and presented in **Figure 2**. Detailed background information of the region's rankings for the ICT business indicators is presented in **Table 82** (Byen Kobenhavn EIPE ID card). ICT business activities are analysed by looking at the following characteristics:

- ICT Business Agglomeration (AgBuss), i.e. location of ICT Scoreboard companies and their affiliates, location of ICT firms, employment and turnover of ICT firms and new investments in the ICT sector (Section),
- ICT Business Internationalisation (IntBuss), i.e. the number of affiliates located outside Denmark that are owned by ICT Scoreboard companies located in Byen Kobenhavn (outward internationalisation) and the number of affiliates located in Byen Kobenhavn that are owned by foreign ICT Scoreboard companies (inward internationalisation),
- ICT Business Networking (NetBuss), i.e. the position of Byen Kobenhavn in a network formed through linkages between regions around the world based on the location and ownership of ICT Scoreboard affiliates.

6.4.1 ICT Business Agglomeration (AgBuss)

The analysis of ICT Business Agglomeration in Byen Kobenhavn starts with the key details on the actors based in Byen Kobenhavn (**Table 97**), their economic performance and an overview of new investments in ICT in. Byen Kobenhavn.

This information is based on the company-level information provided by ORBIS by Bureau Van Dijk (reference years from 2005 to 2012)[74] and data collected in the European Investment Monitor by Ernst&Young for the period 1997-2011. For the methodology of indicator construction see Section 0.

Byen Kobenhavn, given its share in the total EU population, ranks 4th place among the EU regions, for the number of ICT Scoreboard Headquarters it hosts. This is due to the presence of 4 firms that are on the list of the world's top 637 ICT R&D investors. Among these firms are TDC, a telecommunications company; Simcorp, a provider of specialised software and financial expertise for the investment management industry; Thrane & Thrane, a manufacturer of infrastructural solutions and equipment for mobile radio and satellite communication; and Maconomy, a provider of Enterprise Resource Planning software founded in 1989. Together, these ICT Scoreboard firms own 66 (1% of EU total) affiliates located worldwide. This, given Byen Kobenhavn's share in the total EU population, gives it the 61st position in that ranking.

With respect to the affiliates of the 637 ICT Scoreboard Headquarters, 124 of them are in Byen Kobenhavn. In other words, 1% of business affiliates belonging to any ICT Scoreboard Headquarter and based in the EU, is in Byen Kobenhavn. This puts Byen Kobenhavn 23rd in this ranking.

Considering the location of ICT firms in Byen Kobenhavn, according to the ORBIS company level database by Bureau Van Dijk, there are 6 ICT businesses (0.48% of EU total) in the capital of Denmark.[75] Given its size, this places Byen Kobenhavn on the 61st place in this ranking.

[74] The information available about business actors that is used here is the following: Location of ICT Scoreboard Headquarters, number of affiliates owned worldwide by ICT Scoreboard Headquarters based in the observed region, number of ICT Scoreboard affiliates located in the observed region and belonging to any of the ICT Scoreboard Headquarter and, finally, number of ICT firms located in the region.

[75] In order to avoid double-counting, separate searches were run using a filter on consolidation code. In the analysis, companies with consolidated accounts only were selected.

Table 95: ICT Business Agglomeration in Byen Kobenhavn

Indicator ID	Name of indicator	Rank		
AgBuss 1	Location of ICT Scoreboard Headquarters	20	**Number of ICT Scoreboard Headquarters located in Byen Kobenhavn**	**% in EU total**
			4	1%
			ICT Scoreboard Headquarters located in Byen Kobenhavn	
			1. TDC 2. Simcorp 3. Thrane & Thrane 4. Maconomy	
AgBuss 2	Ownership of ICT Scoreboard affiliates	61	**Number of ICT Scoreboard affiliates owned worldwide by ICT Scoreboard Headquarters located in Byen Kobenhavn**	**% in EU total**
			66	1%
AgBuss 3	Location of ICT Scoreboard affiliates	23	**Number of ICT Scoreboard affiliates located in Byen Kobenhavn**	**% in EU total**
			124	1%
AgBuss 4	Location of ICT firms	61	**Number of ICT firms located in Byen Kobenhavn**	**% in EU total**
			6	0.48%

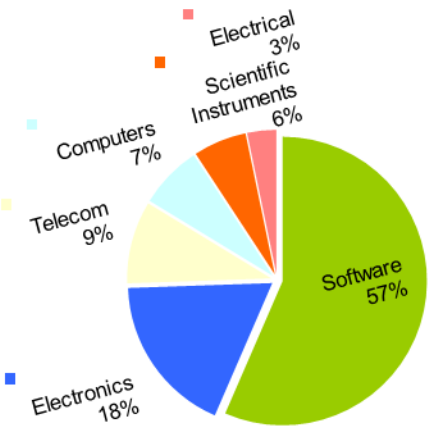
The above-mentioned 6 ICT businesses based in Byen Kobenhavn provide over 0.7% of the EU total employment and generate 0.86% of the total EU total turnover of the considered ICT firms (see **Table 96**). Bearing in mind Byen Kobenhavn's share in the total EU population, this puts this region on the 19th on employment and 15th on turnover respectively. On the other hand, ICT business activity in Byen Kobenhavn has decreased between 2005 and 2012. In this period, the employment and turnover decreased by 10%. As a result, Byen Kobenhavn ranks very low in terms of business dynamics among all the EU Nuts 3 regions.

Table 96: ICT Business Agglomeration in Byen Kobenhavn, cont.

Indicator ID	AgBuss 5	AgBuss 6	AgBuss 7	AgBuss 8
Indicator Name	**ICT employment**	**Growth in ICT employment**	**Turnover by ICT firms**	**Growth in turnover by ICT firms**
Rank	19	1265	15	1264
% in EU total / %	0.72%	-10%	0.86%	-10%

According to the information provided by the European Investment Monitor, between 1997 and 2011, there were nearly 184 new investments in Byen Kobenhavn by companies from the ICT sector (see **Table 97**). This constitutes 2% of all investments considered in the entire EU. Given the share of Byen Kobenhavn's population in the total EU population, it comes 6th in this ranking. A large share of these investments were in the field of software (57%), followed by electronics (18%) and telecommunications (9%).

Table 97: ICT Business Agglomeration in Byen Kobenhavn, cont.

Indicator ID	Name of indicator	Rank		
AgBuss 9	New business investments in the ICT sector	6	**Number of new investments in the ICT sector in Byen Kobenhavn**	**% in EU total**
			184	2%
			Distribution of new investments by activity type	
				

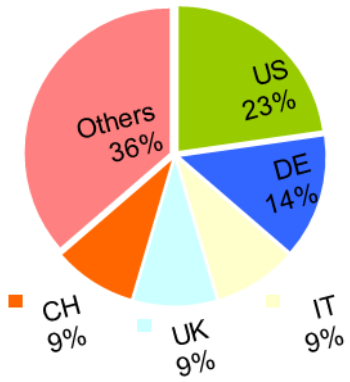
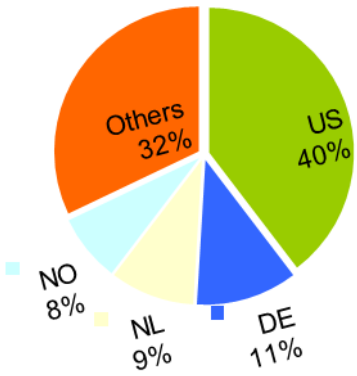
6.4.2 ICT Business Internationalisation (IntBuss)

The analysis of ICT Business Internationalisation is based on the data on the location and ownership of affiliates by 637 ICT Scoreboard Headquarters and refers to 2008. This data comes from the company-level information provided by ORBIS by Bureau Van Dijk. Depending on the perspective, two types of internationalisation are considered, i.e. outward internationalisation measured by the number of affiliates located outside of Ireland that are owned by ICT Scoreboard companies located in Byen Kobenhavn and inward internationalisation measured by the number of affiliates located in Byen Kobenhavn that are owned by foreign ICT Scoreboard companies. For the methodology for indicator construction see Section 0.

Byen Kobenhavn ranks 41st in outward ICT business internationalisation (see Table 98). This is due to the fact that out of 66 affiliates owned by the three ICT Scoreboard Headquarters based in Byen Kobenhavn, 35 affiliates are located outside of Denmark. Their major foreign business activity location includes the US, Germany, Italy, the UK, and Switzerland.

In terms of inward ICT business internationalisation, Byen Kobenhavn ranks 4th. According to the information provided in Table 98, 104 out of 124 affiliates which belong to ICT Scoreboard Headquarters and located in Byen Kobenhavn are of foreign ownership. 40% of all foreign affiliates belong to the ICT Scoreboard Headquarters located in US. Other major owners are based in Germany, the Netherlands and Norway.

Table 98: Outward and inward ICT business internationalisation

Indicator ID	Name of indicator	Rank	
InBuss 1	Outward ICT business internationalisation	41	**Number of affiliates located outside of Denmark that are owned by ICT Scoreboard Headquarters located in Byen Kobenhavn**
			35
			Top foreign locations of affiliates owned by ICT Scoreboard Headquarters located in Byen Kobenhavn
			
InBuss 2	Inward ICT business internationalisation	4	**Number of affiliates located in Byen Kobenhavn that are owned by ICT Scoreboard Headquarters located abroad**
			104
			Origins of ICT Scoreboard Headquarters with affiliates located in Byen Kobenhavn
			

6.4.3 ICT Business Networking (NetBuss)

In order to construct an ICT business network and to assess the position of individual regions in it, we rely on the network analysis of the locations of ICT Scoreboard companies and their affiliates. This is done by linking a region where an ICT Scoreboard company is based with a region where it has at least one of its affiliates. Thus, we identify regions as nodes of the network where either an ICT Scoreboard company or affiliate is located. Bilateral relationships (arcs of the network) exist

between regions whenever an ICT Scoreboard company owns an affiliate in a different region.[76] This way we illustrate the destination of business expansion of ICT Scoreboard companies and the location of ICT business activities.[77] This allows us to construct a set of network measures for each region: the analysis of these measures in the case of Darmstadt is presented below.

Analysing this network of ICT business activity allows us to observe the specific position of Darmstadt in it. It also help us to better understand the region's position in the EIPE ranking and its role in the European ICT landscape.

This analysis focuses on 3 successive steps:

- Byen Kobenhavn's position in the ICT business network, as observed from the links established by the location and ownership of ICT Scoreboard affiliates,
- The characteristics of the ICT innovation ego network[78] of first degree partners of Byen Kobenhavn,
- The list of the Top 20 partners of Byen Kobenhavn in the ICT business network by the total number of outgoing (an affiliate located in Byen Kobenhavn and owned by an ICT Scoreboard company from a different region) and incoming connections (an affiliate owned by an ICT Scoreboard company located in Byen Kobenhavn and located in a different region).

For the methodology of indicators construction see Section 0.

Byen Kobenhavn's position in the ICT business network

According to **Table 99**, which presents the ranking of Byen Kobenhavn in the ICT business network, the results show that Byen Kobenhavn is among the most central nodes in the ICT business network. In particular:

- Byen Kobenhavn comes 19th out of 485 European regions in the **in-degree** ranking in the ICT business network. This indicator is based on the number of affiliates located in Byen Kobenhavn that belong to any of the ICT Scoreboard companies headquartered outside of Byen Kobenhavn in 2008. In this ranking, Byen Kobenhavn is surpassed by, for example, Dusseldorf, Bruxelles and Barcelona and followed by Uusimaa, Utrecht and Munchen, Landkreis.
- Byen Kobenhavn comes 49th out of 243 European regions in the **out-degree** ranking in the ICT business network. This indicator is based on the number of regions in which ICT Scoreboard companies headquartered in Byen Kobenhavn have their business affiliates in year 2008.
- Byen Kobenhavn comes on the 43rd place in the **closeness centrality** ranking for the European regions. This ranking tells us how well connected a region is in terms of distance

[76] For more details on the methodology of constructing a network and its application to ICT innovation, see section 0. For a full description of the methodology of network analysis and indicators applied, see the EIPE methodology report De Prato, G. & Nepelski, D. 2013a. 'Identifying European ICT Poles of Excellence. The Methodology.' *JRC Scientific and Policy Reports*. Seville: JRC-IPTS.

[77] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's new investment and headquarter is located in the same region.

[78] Ego network: a location's ego network is a sub-network of the entire network observed. It is constructed by taking in account exclusively all the location's first degree partners, i.e. all nodes directly connected with that location and the connections between them.

to other nodes in the network. Thus, Byen Kobenhavn is shown to be rather **close to** other regions of the ICT business network.

- Byen Kobenhavn comes 25th in the **betweenness ranking** which reflects the position of a node as a hub in the network. Byen Kobenhavn has a very strong **intermediary role** between other nodes of the ICT business network, as compared to the other European regions. In this ranking, it is surpassed only by Cambridgeshire, Utrecht, Bruxelles, and Surrey, and followed by Warszawa, Kobenhavns omegn and Weissenburg-Gunzenhausen.
- Byen Kobenhavn comes 73rd in the **eigenvector centrality** ranking, reflecting the importance of a region in a network based on the role of its neighbours in the ICT business network. Thus, it seems that Byen Kobenhavn is not only connected to very well-connected nodes and, instead a large share of its partners does not include the most central nodes in the network.

Table 99: Byen Kobenhavn's ranks in the ICT business network by network measures

Indicator ID	NetRD 1	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Indicator Name	**In-degree in ICT business network**	**Out-degree in ICT business network**	**Closeness centrality in ICT business network**	**Betweenness centrality in ICT business network**	**Eigenvector centrality in ICT business network**
Rank	19	49	43	25	73

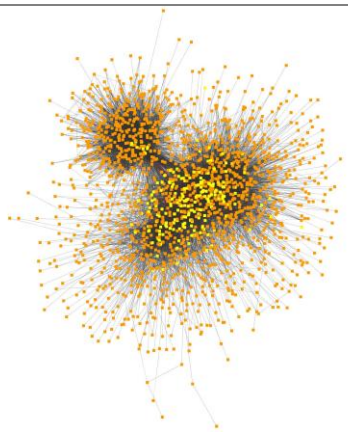
The characteristics of Byen Kobenhavn's ego network

In order to get a deeper insight into the role of Byen Kobenhavn in the ICT business network, we have constructed Byen Kobenhavn's ego network, i.e. a network consisting of Byen Kobenhavn (ego) together with the actors it is connected to (alters) and all the links among those alters. Ego networks are also known as neighbourhood networks or first degree neighbourhoods of ego (Everett and Borgatti 2005). Thus, Byen Kobenhavn's ego network is a sub-network of the ICT business network and is constructed by taking in account only Byen Kobenhavn's first degree partners, i.e. nodes directly connected with Byen Kobenhavn and the links between them.

The characteristics of this ego network are compared with those of the full ICT business network to see whether there are structural differences between the full network and that of the selected node, Byen Kobenhavn, and its direct partners. This way, we can understand better Byen Kobenhavn's neighbourhood in the ICT business network and, by casting some light on the attributes of its neighbours, see how well it is embedded in the ICT business network.

An illustration of the full ICT business network and its sub-network formed by Paris's first degree partners (yellow nodes) is given in **Figure 28**. **Table 100** summarises the main measures of the Byen Kobenhavn ego network and compares it to the full ICT business network.

Figure 28: The ICT business network and the ego network of Byen Kobenhavn



Note: The graph represents the full ICT business network together with the ego network formed by Byen Kobenhavn's first degree partners represented by yellow nodes.

According to **Table 100**, Byen Kobenhavn's ego network includes 73 individual regions connected directly to Byen Kobenhavn, i.e. over 4% of the regions in the full ICT business network. Altogether these regions form nearly 800 linkages, i.e. around 4% of the linkages in the entire network.

The density measure, i.e. a ratio of the actual number of links to the number of possible links, shows how well the network is connected. Byen Kobenhavn's ego network shows a **density** of 0.257, as compared to 0.01 for the full ICT business network. Thus, Byen Kobenhavn's ego network is significantly denser than that of the full ICT business network. This is related to the fact that there are a small number of nodes in Byen Kobenhavn's ego network, as compared to the full network. Moreover, as illustrated in Table 101, there are a considerable number of large and well-connected nodes.

The clustering coefficient measures the degree to which regions in a network form tightly connected groups by linking with each other. Byen Kobenhavn's ego network scores 0.683 which is significantly higher than the score for the full ICT business network. This indicates that the regions present in Byen Kobenhavn's ego network are clustered in much better connected groups as compared to all the regions in the full ICT business network. The fact is that Byen Kobenhavn is connected to generally better connected nodes than Byen Kobenhavn itself, which in turn are also very likely to be well-connected among them.

The **network centralization** level measures how central a network's most central region is in relation to how central all the other regions are, i.e. how equal nodes are in terms of their position in the network. Byen Kobenhavn's ego network scores 0.764, as compared to 0.271 for the full ICT business network. Thus, because the variation in the nodes' centrality level in the ego network is significantly higher than in the full network, there is a greater level of inequality between the nodes in Byen Kobenhavn's ego network than between the nodes in the full network in terms of their position in the network. This might indicate that, for example, in the ego network there are very few nodes with high level of centrality and numerous nodes that play less central roles. Again, this is well exemplified by the list of Byen Kobenhavn's top 20 partners, which includes some of the main nodes of the ICT business network.

The **distance**[79] between any two nodes in the Byen Kobenhavn's ego network, measured by the average path length, is 1.7, as compared to 2.7 in the full network. Thus, due to a denser web of

[79] The distance between two nodes is given by the shortest path connecting them and it is equal to the number of edges separating the two nodes. Average path length is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs. This shows us, on average, the number of steps it takes to get from one member of the network to another.

connections between the regions in the ego network, the distance between any two regions is shorter than it is in the full ICT business network.

The **average number of direct neighbours** of the regions included in the Byen Kobenhavn's ego network is 18, i.e. nearly as many as an average node in the full network.

Table 100: Characteristics of Byen Kobenhavn's network vs. full ICT business network

Network-Level Measure	Full ICT business network	Byen Kobenhavn's ego network
Node Count	1,840	73
Link Count	18,180	793
Density	0.010	0.257
Clustering Coefficient	0.408	0.683
Network centralization	0.271	0.764
Average path length	2.817	1.743
Average number of neighbours	18.641	18.493

Top 20 partners of Byen Kobenhavn in the ICT business network by in- and out-degree

Table 101 lists Byen Kobenhavn's top 20 partners in the ICT business network by two measures in the ICT business network. The first one, i.e. in-degree, tells us about the number of affiliates located in Byen Kobenhavn and owned by ICT Scoreboard companies headquartered in other regions in the world. The second one, i.e. out-degree, refers to the number of affiliates owned by ICT Scoreboard companies headquartered in Byen Kobenhavn and located in other regions around the world.

Regarding the in-degree ranking, the top 20 regions (of 25 in total) in which there is at least one ICT Scoreboard company with affiliates in Byen Kobenhavn, account for 41 affiliates based in this region i.e. 88% of all ICT Scoreboard affiliates located in Byen Kobenhavn. ICT Scoreboard companies with affiliates in Byen Kobenhavn are from Oslo, Stockholms län and Inner London East. A large share of the regions includes those that are located outside of Europe, mainly in the US.

Concerning the out-degree ranking, the top 20 regions (of 55 in total) in which there is at least one affiliate of an ICT Scoreboard firm headquartered in Byen Kobenhavn, account for altogether 72 affiliates. This represents 66% of the affiliates owned by Byen Kobenhavn ICT Scoreboard companies and located outside of Byen Kobenhavn. The main business destinations of Byen Kobenhavn ICT Scoreboard companies include Washington, Stockholms län and Hamilton. Again, there are many non-European regions where Byen Kobenhavn ICT Scoreboard companies tend to locate their business affiliates.

Table 101: Top 20 partners of Byen Kobenhavn in the ICT business network by in- and out-degree

In-degree: Number of affiliates located in Byen Kobenhavn and owned by ICT Scoreboard companies headquartered in ...				Out-degree: Number of affiliates owned by ICT Scoreboard companies headquartered in Byen Kobenhavn and located in ...			
Nr	**Region Code**	**Region name**	**Nr**	**Nr**	**Region Code**	**Region name**	**Nr**
1	NO011	Oslo	5	1	3730	WASHINGTON	14
2	SE110	Stockholms län	5	2	SE110	Stockholms län	10
3	UKI12	Inner London East	3	3	49	HAMILTON	5
4	375	ZURICH	2	4	DK050	Nordjylland	3
5	DE718	Hochtaunuskreis	2	5	FI181	Uusimaa	3
6	DK012	Københavns omegn	2	6	IE021	Dublin	3
7	DK042	Østjylland	2	7	2868	MINNEAPOLIS	3
8	DK050	Nordjylland	2	8	AT342	Rheintal-Bodenseegebiet	3
9	ES300	Madrid	2	9	BE211	Arr. Antwerpen	3
10	1656	BEAVERTON	1	10	FR101	Paris	3
11	1841	CARLSBAD	1	11	NL326	Groot-Amsterdam	3
12	232	BASEL	1	12	NL414	Zuidoost-Noord-Brabant	3
13	3695	VIRGINIA BEACH	1	13	UKI12	Inner London East	2
14	3850	WOBURN	1	14	DK042	Østjylland	2
15	BE212	Arr. Mechelen	1	15	2814	MELBOURNE	2
16	DEF05	Dithmarschen	1	16	2933	MOUNTAIN VIEW	2
17	DEF09	Pinneberg	1	17	3159	PEABODY	2
18	FI181	Uusimaa	1	18	3355	ROUND ROCK	2
19	FR104	Essonne	1	19	3393	SAN JOSE	2
20	IE021	Dublin	1	20	BE100	Arr. de Bruxelles-Capitale	2
Total top 20			**36** (88% in total)	**Total top 20**			**72** (66% in total)
Total			**41**	**Total**			**109**

6.5 Conclusions

This section presents a short summary of the key findings on the ICT activity in Byen Kobenhavn according to the framework depicted in **Figure 2**.

ICT R&D

Concerning **ICT R&D agglomeration**, Byen Kobenhavn shows a mixed image. It benefits of the presence of two universities listed by the QS World University Ranking and their high scientific output (1% of the EU total). Also research organizations and private firms based in Byen Kobenhavn seem to be very active in the FP7 programs. Due to the presence of Thrane & Thrane, TDC and SIMCORP Byen Kobenhavn is a place of control over large amounts of business R&D expenditures. However, similar to the case of Inner London East, the private ICT R&D infrastructure is virtually

non-existent. In other words, despite the presence of large companies in Byen Kobenhavn that influence the ICT R&D activity in Europe, the actual R&D activities are performed outside of the region.

As, Byen Kobenhavn does not host private R&D centers that would belong to major semiconductor influencers (IHS iSuppli criteria), **ICT R&D internationalisation** is seen as slow.

Still, Byen Kobenhavn is among the top 60 European regions in the **ICT R&D network**, i.e. among the top 10% of all nodes. It is as a mid-sized node with sound connections to a large part of the network. In particular, the composition of its neighbourhood, i.e. regions to which it is linked directly, shows that it is very well connected with a majority of nodes and with the key ones in particular. In addition, Byen Kobenhavn shows to be well connected with a particular selection of less central but neighbouring regions, in particular from Sweden and the Netherlands. This way, though less central, Byen Kobenhavn maintains probably a specialised role in the ICT R&D network.

ICT Innovation

Regarding **ICT innovation agglomeration**, Byen Kobenhavn shows high investments in intangibles by private businesses, which is the result of the presence of large ICT companies. In addition, Byen Kobenhavn holds the 4th place, following Inner London East and Cambridgeshire CC, in the number of venture capital deals. The areas of activity of these new companies ranges from Domain Portfolio Management services through broadband solutions and network-based security up to monitoring solutions of machinery health and predictive maintenance information for oil and gas, maritime, and power generation industries. This image of innovative region is slightly weakened by the relatively low score in the ICT innovation output measured by the number of ICT patents. This is likely to be related to the lack of a strong private ICT R&D infrastructure.

Considering **internationalisation of ICT innovation**, Byen Kobenhavn stands high, proportionally to its innovation output. The main partners in ICT co-inventing activity of Byen Kobenhavn-based inventors are from Finland, the US, Sweden, the UK and Germany.

Byen Kobenhavn holds a fair position in the **ICT innovation network**. The analysis reveals that it is among the top 70 of all EU regions. As in the case of ICT R&D network, inventors from Byen Kobenhavn maintain sound connections with some Scandinavian regions. However, at the same time, links with distant regions in the US or China are also present.

ICT Business

In terms of **ICT business agglomeration**, Byen Kobenhavn can be characterized as a region with strong and diverse ICT business activity. On the one hand, the region hosts 4 ICT Scoreboard Headquarters and, on the other hand, it is a rather popular location among other ICT Scoreboard Headquarters, which host their affiliates in the Danish capital. As a result, it holds a 23rd place in terms of location of business affiliates of the largest ICT R&D investors worldwide. Byen Kobenhavn plays an important role in Europe judged by the economic performance of Byen Kobenhavn-based firms. However, like in other large agglomerations of business activity, a recent decrease in employment and turnover has been observed.

The level of **ICT business internationalisation** in Byen Kobenhavn is high. In particular, the region stands out in terms of inward internationalisation. This is a result of the above mentioned attractiveness of Byen Kobenhavn among the largest ICT R&D investors. The major investors include firms from the US, Germany, the Netherlands and Norway.

Byen Kobenhavn plays also a strong position in the **ICT business network**, as an important business destination among the ICT Scoreboard companies. In addition, it also seems to play an important intermediary role between different parts of the network. This is illustrated by the strong connection with Scandinavian countries, on the one hand, and the US, on the other hand. As a result, it can be considered as a medium- sized node, with a specific role of bridging between various parts of the network.

Summing up, Byen Kobenhavn emerges as an important element of the European ICT landscape. The region has a balanced performance in ICT R&D and innovation activities, but its main strength comes from the sound ICT business foundations. Byen Kobenhavn holds a valuable position in all types of ICT networks. This is particularly visible through its strong connections with both Scandinavian regions as well as with geographically distant locations, e.g. Silicon Valley. It gives Byen Kobenhavn a strong intermediary role between different parts of the network, which in turns, may be the result of technological specialisation in the Danish capital.

7. Annex I: EIPE indicators

Table 102 offers a schematic presentation of the organisation of the EIPE indicators around the three activities and their three characteristics, as observed in this study. It only serves as a visual tool to capture the overall organization and labelling of the indicators.

Table 102: An overview of groups of indicators for the measurement of activities and characteristics of EIPE

	ICT activities		
Characteristics	**R&D**	**Innovation**	**Business**
Agglomeration	Agglomeration of R&D activities AgRD	Agglomeration of Innovation activities AgIn	Agglomeration of Business activities AgBuss
Internationalisation	Internationalisation of R&D activities IntRD	Internationalisation of Innovation activities: IntIn	Internationalisation of R&D activities: IntBuss
Networking	Networking of R&D activities NetRD	Networking of Innovation activities NetIn	Networking of Business activities NetBuss

The full list of EIPE indicators meeting the characteristics specified by the definition, framework and criteria, can be found in **Table 103**. They are presented together with a first indication of the data sources used and their time coverage. Those indicators and their characteristics are further described in the next chapter of this report. A detailed description of specific methodologies applied to elaborate each indicator, as well as the data sources used, is given in detail in the Annexes.

Table 103: Overview of the EIPE indicators: the EIPE ID card

Activity	Characteristic	Name of Indicator	Indicator ID	Nr
R&D	Agglomeration	Universities ranked in the QS University Ranking	AgRD 1	1
		Academic ranking of a Computer Science faculty	AgRD 2	2
		Employer ranking of a Computer Science faculty	AgRD 3	3
		Citations ranking of a Computer Science faculty	AgRD 4	4
		R&D expenditures by ICT firms	AgRD 5	5
		FP7 funding to private organisations	AgRD 6	6
		FP7 participations	AgRD 7	7
		FP7 funding to SMEs	AgRD 8	8
		FP7 participations by SMEs	AgRD 9	9
		Location of ICT R&D centres	AgRD 10	10
		Ownership of ICT R&D centres	AgRD 11	11
		Scientific publications in Computer Science	AgRD 12	12
	Internationalisation	Outward ICT R&D internationalisation	IntRD 1	13
		Inward ICT R&D internationalisation	IntRD 2	14
	Networking	Degree in ICT R&D network	NetRD 1	15
		Closeness centrality in ICT R&D network	NetRD 2	16
		Betweenness centrality in ICT R&D network	NetRD 3	17
		Eigenvector centrality in ICT R&D network	NetRD 4	18
Innovation	Agglomeration	Investment in intangibles by ICT firms	AgIn 1	19
		Venture Capital financing to ICT firms	AgIn 2	20
		ICT patents	AgIn 3	21
	Internationalisation	International co-inventions	IntIn 1	22
	Networking	Degree in ICT innovation network	NetIn 1	23
		Closeness centrality ICT innovation network	NetIn 2	24
		Betweenness centrality ICT innovation network	NetIn 3	25
		Eigenvector centrality ICT innovation network	NetIn 4	26
Business	Agglomeration	Location of ICT Scoreboard Headquarters	AgBuss 1	27
		Ownership of ICT Scoreboard affiliates	AgBuss 2	28
		Location of ICT Scoreboard affiliates	AgBuss 3	29
		Location of ICT firms	AgBuss 4	30
		ICT employment	AgBuss 5	31
		Growth in ICT employment	AgBuss 6	32
		Turnover by ICT firms	AgBuss 7	33
		Growth in turnover by ICT firms	AgBuss 8	34
		New business investments in the ICT sector	AgBuss 9	35
	Internationalisation	Outward ICT business internationalisation	IntBuss 1	36
		Inward ICT business internationalisation	IntBuss 2	37
	Networking	In-degree in ICT business network	NetBuss 1	38
		Out-degree in ICT business network	NetBuss 2	39
		Closeness centrality in ICT business network	NetBuss 3	40
		Betweenness centrality in ICT business network	NetBuss 4	41
		Eigenvector centrality in ICT business network	NetBuss 5	42

7.1 ICT R&D activities indicators

7.1.1 Agglomeration of ICT R&D (AgRD)

The 12 indicators characterising the agglomeration of ICT R&D activity are listed and described in **Table 104**. They are presented together with a first indication of the data sources used and their time coverage. With 12 different measurements, these indicators cover a broad range of aspects related to inputs and outputs of R&D. In particular, they acknowledge the importance given in EIPE to the presence and the quality of major knowledge production organisations, such as universities (and their computer science departments), private and public research centres (in particular those of multinational companies), innovative SMEs,[80] and also R&D expenditures or bibliometrics output.

Table 104: ICT R&D Agglomeration indicators (AgRD)

Indicator ID	AgRD 1	AgRD 2	AgRD 3	AgRD 4	AgRD 5	AgRD 6
Name of indicator	**Universities ranked in the QS University Ranking**	**Academic ranking of a Computer Science faculty**	**Employer ranking of a Computer Science faculty**	**Citations ranking of a Computer Science faculty**	**R&D expenditures by ICT firms**	**FP7 funding**
What does it measure?	Measures the number of universities in QS university ranking	Measures the performance of the Computer Science faculty according to the academic ranking of QS	Measures the performance of the Computer Science faculty according to the employer ranking of QS	Measures the performance of the Computer Science faculty according to the citations ranking of QS	Measures the average annual amount spent on R&D in the ICT sector	Measures the amount received for research in ICT R&D
Unit of measurement	Region's share in the total number of EU ranked universities to a region's share in the EU population	The highest rank of a Computer Science faculty in the academic ranking	The highest rank of a Computer Science faculty in the employer ranking	The highest rank of a Computer Science faculty in citations ranking	Region's share in the R&D expenditures by ICT firms in the EU to a region's share in the EU population	Region's share in the total EU ICT FP7 funding to a region's share in the EU population
Definition of ICT dimension	None	Computer science faculty			Based on NACE Rev. 2	ICT areas of the FP7 programme (see Section 0)
Unit of observation	NUTS 3					
Source	9.1 QS World University Rankings by **QS** (see Section0)				9.7 Company-level information: ORBIS by Bureau Van **Dijk** (see Section 0)	9.2 ICT FP7 funding: FP7 database by EC DG **Connect** (see Section 0)
Reference year(s) considered	2011				2005-2011	2007-2011

[80] In order to account for the differences of size of the NUTS3 regions, normalization with respect to the number of inhabitants is made. A modified version of the Balassa index is used, as defined in De Prato, G. & Nepelski, D. 2013a. 'Identifying European ICT Poles of Excellence. The Methodology.' *JRC Scientific and Policy Reports*. Seville: JRC-IPTS.. This index aims to measure the *relative* agglomeration level of the given R&D activities in each region. The indicators for which this relative measure is used include indicators from AgR&D 5 to AgR&D 12.

(continued): ICT R&D Agglomeration indicators (AgRD)

Indicator ID	AgRD 7	AgRD 8	AgRD 9	AgRD 10	AgRD 11	AgRD 12
Name of indicator	**FP7 participations**	**FP7 funding to SMEs**	**FP7 participations by SMEs**	**Location of ICT R&D centres**	**Ownership of ICT R&D centres**	**Scientific publications in Computer Science**
What does it measure?	It measures the total number of ICT R&D FP7 projects to which organisations, located in the observed region, have participated to	It measures the total amount of ICT R&D FP7 funding given to SMEs located in the observed region	It measures the total number of ICT R&D FP7 projects to which SMEs, located in the observed region, have participated to	It measures the total number of ICT R&D centres located in the observed region	It measures the total number of ICT R&D centres owned worldwide by companies located in the observed region	It measures the total number of scientific publications , in the Computer Science area produced by organisations located in the observed region
Unit of measurement	Region's share in the total number of ICT FP7 participations to a region's share in the EU population	Region's share in the total EU ICT FP7 funding to SMEs to a region's share in the EU population	Region's share in the total number of ICT FP7 SMEs participations to a region's share in the EU population	Region's share in the total number of R&D centres located in the EU to a region's share in the EU population	Region's share in the total number of R&D centres owned by EU firms to a region's share in the EU population	Region's share in the total number of publications in Computer Science to a region's share in the EU population
Definition of ICT dimension	ICT areas of the FP7 programme			Based on HIS iSuppli classification of the major "semiconductors influencers"		Computer Science as defined by Web of Science® classification of Research Areas
Unit of observation	NUTS 3					
Source	9.2 ICT FP7 funding: FP7 database by EC DG **Connect** (see Section 0)			9.4 ICT R&D centre location: Design Activity Tool by IHS **iSuppli** (see Section 0)		9.3 Bibli ometrics: Web of Science by Thomson **Reuters** (see Section 0)
Reference year(s) considered	2007-2011			2012		2000-2012

7.1.2 Internationalisation of ICT R&D (IntRD)

To address the issue of internationalisation of ICT-related R&D activity in NUTS3 level spatial units across the EU, a distinction between in- and outward internationalization of R&D activities based in a location is made. The 2 indicators characterising the internationalisation of ICT R&D activity are listed and described in **Table 105**.

Table 105: ICT R&D Internationalisation indicators (IntRD)

Indicator ID	IntRD 1	IntRD 2
Name of indicator	**Outward ICT R&D internationalisation**	**Inward ICT R&D internationalisation**
What does it measure?	It measures the number of ICT R&D centres located abroad (outside the country) that are owned by companies' headquarters located in a region	It measures the number of ICT R&D centres located in a region that are owned by foreign companies
Unit of measurement	Region's share in the total number of R&D centres located abroad that are owned by companies' headquarters located in the EU to a region's share in the EU population	Region's share in the total number of R&D centres owned by foreign companies in the EU to a region's share in the EU population
Definition of ICT dimension	Based on HIS iSuppli classification of the major "semiconductors influencers" (see Section 0)	
Unit of observation	NUTS 3	
Source	9.4 ICT R&D centre location: Design Activity Tool by IHS **iSuppli** (see Section 0)	
Reference year(s) considered	2012	

7.1.3 Networking in ICT R&D (NetRD)

A set of networking measures with addressing the R&D activity is constructed and it relies on the network analysis of the locations of FP7 programmes participants. Below, the key elements of the network are described. ICT R&D Networking indicators are listed in **Table 106: ICT R&D Networking indicators (NetRD)**. For a full description of the methodology of network analysis and indicators applied, see section 0. The data source on FP7 programmes is described in section 0.

Network design: A straightforward way of representing the locations of FP7 programmes participants as a network is through drawing a line connecting two different regions whenever two organizations from these regions participate in the same FP7 programme (Cassi et al. 2008). Thus, knowing the location of each participant, we can build a directed network. In a formal way, we identify our set of nodes, *V*, as the regions where FP7 programmes partners are located, and the set of arcs, *A*, as the bilateral relationships that exist whenever an organization from one region participates in a FP7 programme together with an organization from a different region.[81]

Actors: NUTS 3 regions located in the EU 27.

Relationships: A link between two regions exists whenever an organization from one region participates in a FP7 programme together with an organization from a different region.

Data source: The analysis is conducted using the data on FP7 programmes by GD Connect and is described in section 0.

Network measures: According to the above defined methodology, based on the number of connections between regions and a subsequent analysis of these connections indicators are constructed. Their list and description can be found in 0.

[81] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's R&D centre and headquarter are located in the same region.

Table 106: ICT R&D Networking indicators (NetRD)

Indicator ID	NetRD 1	NetRD 2	NetRD 3	NetRD 4
Name of indicator	**Degree in ICT R&D network**	**Closeness centrality in ICT R&D network**	**Betweenness centrality in ICT R&D network**	**Eigenvector centrality in ICT R&D network**
What does it measure?	It measures the total number of connections a region maintains with other regions through organizations participating in common ICT FP7 projects	It measures the average distance that each node is from all other nodes in the network	It measures the number of shortest paths in a network that traverse through that node	It measures the importance of a node in a network, based on the importance of its direct neighbours
Unit of measurement	Rank between 0 and 1.			
Definition of ICT dimension	ICT areas of the FP7 programme (see Section 0)			
Unit of observation	NUTS 3			
Source	9.2 ICT FP7 funding: FP7 database by EC DG **Connect** (see Section 0)			
Reference year(s) considered	2007-2011			

7.2 ICT innovation activities indicators

7.2.1 Agglomeration of ICT innovation (AgIn)

As in the case of the R&D activities, the set of indicators used to quantify and map innovation across the EU is composed of indicators dealing with agglomeration of innovation activity in NUTS3 level spatial units. To the extent allowed by the availability of indicators and data, a mix of measures capturing the input and outputs of innovation activities is proposed. Table 107 lists and describes all the indicators.

Table 107: ICT Innovation Agglomeration indicators (AgIn)

Indicator ID	AgIn 1	AgIn 2	AgIn 3
Name of indicator	**Investment in intangibles by ICT firms**	**Venture Capital financing to ICT firms**	**ICT patents**
What does it measure?	Measures the average annual amount spent on intangibles in the ICT sector	Measures the amount of venture capital invested in the ICT sector	It measures the amount of ICT patent applications with inventors residing in the region
Unit of measurement	Region's share in the total investments in intangibles by ICT firms in the EU to a region's share in the EU population	Region's share in the total VC funding in to ICT firms in the EU to a region's share in the EU population	Region's share in the total number of ICT patents in the EU to a region's share in the EU population
Definition of ICT dimension	Based on NACE Rev. 2	Based on the Dow Jones classification of industry segments (see Section 0)	Based on the OECD definition of ICT patents following IPC taxonomy (OECD 2008)
Unit of observation	NUTS 3		
Source	9.7 Company-level information: ORBIS by Bureau Van **Dijk** (see Section 0)	9.8 Venture capital: VentureSource by Dow **Jones** (Section 0)	9.6 Patent data: REGPAT by **OECD** (Section 0)
Reference year(s) considered	2005-2012	2000-2012	2000-2009

7.2.2 Internationalisation of ICT innovation (IntIn)

Regarding the internationalization of innovation, patent-based indicators are used. The analysis uses measures of internationalisation that are based on the presence of inventors residing in different regions of the world among the list of inventors. An international patent application is defined in the analysis presented here as a patent application that includes at least two inventors residing in different countries. Using this methodology, we use the concept of internationalisation of innovation measured by international co-invention. This concept is used to construct a relative measure of international collaboration between inventors.

The data on regional patents represents the input to innovation activities and the relevant data originates from the Regpat database (see Section 0).

Table 108: ICT Innovation Internationalisation indicators (IntIn)

Indicator ID	**IntIn 1**
Name of indicator	**International co-inventions**
What does it measure?	It measures the number of international ICT patents, i.e. patents with at least two inventors residing in different countries, and attributes to the observed region the (fractional) count) of those patents for which at least one inventor is residing in the region.
Unit of measurement	Region's share in the total number of international ICT patents in the EU to a region's share in the EU population
Definition of ICT dimension	Based on the OECD definition of ICT following IPC taxonomy (OECD 2008).
Unit of observation	NUTS 3
Source	9.6 Patent data: REGPAT by **OECD** (Section 0)
Reference year(s) considered	2000-2009

7.2.3 Networking in ICT innovation (NetIn)

A set of networking measures with addressing the innovation activity is constructed and it relies on the network analysis of the location of inventors based in different locations and jointly developing ICT inventions. Below, the key elements of the network are described. ICT Innovation Networking indicators are listed in **Table 109**. For a full description of the methodology of network analysis and indicators applied, see Section 0.

Network design: To construct a network depicting the concept of innovation networking a network of technological collaborations between inventors based on patent data is built. The methodology was proposed by Breschi, Cassi and Malerba (2007) and used by De Prato and Nepelski (2012). This approach uses the information that each patent application has a list of inventors, i.e. the people who developed a particular invention, and information about their place of residence.

Actors: NUTS3 regions located in the EU27 and TL3 regions in the remaining OECD countries.

Relationships: An intuitive way of representing the set of inter-regional or international co-inventions by using patent data as a network is through drawing a line connecting two regions that share a patent developed by their residents. By doing this for the entire pool of co-inventions, we are able to construct a network of technological collaborations.

The relationship between different locations can be described as the total sum of co-inventions developed by inventors residing in different regions. According to (Guellec and Van Pottelsberghe de la Potterie 2001), the total number of patents co-invented by residents of region *i* in collaboration with researchers in other regions is

$$CoInn_i = \sum_{j \neq i} CoInn_{ij} \,. \qquad (1)$$

Data source: The analysis is conducted using the data on REGPAT by OECD (see section 0).

Network measures: In the above context, based on the number of connection of a region, we can define the measures of regions' centrality. All indicators listed in **Table 109**.

Table 109: ICT Innovation Networking indicators (NetIn)

Indicator ID	NetIn 1	NetIn 2	NetIn 3	NetIn 4
Name of indicator	**Degree in ICT innovation network**	**Closeness centrality in ICT innovation network**	**Betweenness centrality in ICT innovation network**	**Eigenvector centrality in ICT innovation network**
What does it measure?	It measures the total number of connections a region maintains with other regions through joint inventions	It measures the average distance that each node is from all other nodes in the network	It measures the number of shortest paths in a network that traverse through that node	It measures the importance of a node in a network, based on the importance of its direct neighbours
Unit of measurement	Rank between 0 and 1	Rank between 0 and 1	Rank between 0 and 1	Rank between 0 and 1
Definition of ICT dimension	Based on the OECD definition of ICT following IPC taxonomy (OECD 2008).			
Unit of observation	NUTS 3 for EU and TL3 for the remaining OECD countries			
Source	9.6 Patent data: REGPAT by **OECD** (Section 0)			
Reference year(s) considered	2000-2009			

7.3 ICT business activities indicators

7.3.1 Agglomeration of business activities (AgBuss)

As in the case of the R&D and innovation activities, the set of indicators used to quantify and map business across the EU is composed of indicators related to agglomeration of business activity in NUTS3 spatial units. In addition, to the extent allowed by the availability of indicators and data, a mix of measures capturing the input and outputs of business activities is proposed. **Table 110** lists the relevant indicators.

Table 110: ICT Business Agglomeration indicators (AgBuss)

Indicator ID	AgBuss 1	AgBuss 2	AgBuss 3	AgBuss 4	AgBuss 5
Name of indicator	**Location of ICT Scoreboard Headquarters**	**Ownership of ICT Scoreboard affiliates**	**Location of ICT Scoreboard affiliates**	**Location of ICT firms**	**ICT employment**
What does it measure?	It measures the number of ICT Scoreboard Headquarters located in the observed region	It measures the number of ICT Scoreboard affiliates owned worldwide by ICT Scoreboard Headquarters located in the observed region	It measures the total number of ICT Scoreboard affiliates located in the observed region	It measures the number of ICT firms located in the observed region	It measures the total employment in ICT firms in the observed region
Unit of measurement	Region's share in the total number of ICT Scoreboard Headquarters located in the EU to a region's share in the EU population	Region's share in the total number of ICT Scoreboard affiliates owned by EU ICT Scoreboard Headquarters to a region's share in the EU population	Region's share in the total number of ICT Scoreboard affiliates located in the EU to a region's share in the EU population	Region's share in the total number of ICT firms located in the EU to a region's share in the EU population	Region's share in the total employment by ICT firms located in the EU to a region's share in the EU population
Definition of ICT dimension	Based on NACE Rev. 2				
Unit of observation	NUTS 3				
Source	9.7 Company-level information: ORBIS by Bureau Van **Dijk** (see Section 0)				
Reference year(s) considered	2008	2008	2008	2008	2005-2011

(continued): ICT Business Agglomeration indicators (AgBuss)

Indicator ID	AgBuss 6	AgBuss 7	AgBuss 8	AgBuss 9
Name of indicator	**Growth in ICT employment**	**Turnover by ICT firms**	**Growth in turnover by ICT firms**	**New business investments in the ICT sector**
What does it measure?	It measures employment growth in ICT firms in the observed region	It measures the average annual turnover by ICT firms in the observed region	It measures turnover growth in ICT firms in the observed region	It measures the number of new investments in the ICT sector in the observed region
Unit of measurement	Growth rate in %	Region's share in the total turnover by ICT firms located in the EU to a region's share in the EU population	Growth rate in %	Region's share in the total number of new investments in the ICT sector to a region's share in the EU population
Definition of ICT dimension	Based on NACE Rev. 2			
Unit of observation	NUTS 3			
Source	9.7 Company-level information: ORBIS by Bureau Van **Dijk** (see Section 0)			9.5 European Investment Monitor by Ernst & **Young**

				(Section 0)
Reference year(s) considered	2005-2011	2005-2011	2005-2011	2000-2011

7.3.2 Internationalisation of ICT business activities (IntBuss)

Concerning the internationalization of business activity, it is proxied by the information on the location of business affiliates owned by companies belonging to the ICT Scoreboard, which themselves are based abroad. The details of the indicator measuring the level of internationalisation of business activity in a region are given in **Table 111**.

Table 111: ICT Business Internationalisation indicators (IntBuss)

Indicator ID	IntBuss 1	IntBuss 2
Name of indicator	**Outward ICT business internationalisation**	**Inward ICT business internationalisation**
What does it measure?	It measures the number of affiliates located abroad (outside the country) that are owned by ICT Scoreboard Headquarters located in a region	It measures the number of affiliates located in a region that are owned by ICT Scoreboard Headquarters located abroad
Unit of measurement	Region's share in the total number of affiliates located abroad that are owned by European ICT Scoreboard Headquarters to a region's share in the EU population	Region's share in the total number of affiliates owned by foreign ICT Scoreboard Headquarters in the EU to a region's share in the EU population
Definition of ICT dimension	Based on NACE Rev. 2	
Unit of observation	NUTS 3	
Source	9.7 Company-level information: ORBIS by Bureau Van **Dijk** (see Section 0)	
Reference year(s) considered	2008	

7.3.3 Networking in ICT business activities (NetBuss)

A set of networking measures addressing the business activity is constructed and it relies on the network analysis of the location of companies belonging to the ICT Scoreboard and their affiliates. Below, the key elements of the network are described. ICT Innovation Networking indicators are listed in **Table 112**. For a full description of the methodology of network analysis and indicators applied, see section 0.

Network design: In order to address the issue of networking in the context of business activity, a network of international affiliates is created. A natural way of constructing a network of foreign affiliates is through the ownership and location relationship. This way, a line between each pair of regions is drawn whenever a firm from one region owns an affiliate in another region, or vice versa. This way we illustrate the destination of expansion of multinational enterprises (MNEs) and the location of business activities. This allows us to track the existence of business relationships between regions. By doing this for all the regions owning and hosting subsidiaries of the MNEs, we are able to create a unique map of ownership and location of business affiliates.[82]

Actors: NUTS3 regions located in the EU 27 and TL3 regions in the remaining OECD countries.

Relationships: A link between two regions exists whenever a company from one region invests into a new business activity in a different region. The direction of a link goes from a region where the investing company is located to the region in which investment is made.

[82] In the following, we focus our attention on bilateral relationships between regions and do not take into account loops, i.e. when a company's new investment and headquarter is located in the same region.

Data source: The analysis is conducted using the EIM data on foreign investments (see section 0).

Network measures: In the above context, based on the number of incoming and outgoing connection to and from a region, the measures of regions' centrality are listed in **Table 112**.

Table 112: ICT Business Networking indicators (NetBuss)

Indicator ID	**Net Bus 1**	**Net Bus 2**	**Net Bus 3**	**Net Bus 4**	**Net Bus 5**
Name of indicator	**In-degree in ICT business network**	**Out-degree in ICT business network**	**Closeness centrality in ICT business network**	**Betweenness centrality in ICT business network**	**Eigenvector centrality in ICT business network**
What does it measure?	It measures the total number of connections a region maintains with other regions whenever an ICT Scoreboard Headquarters located in that region owns an affiliate located in other regions	It measures the total number of connections a region maintains with other regions by hosting affiliates owned by ICT Scoreboard Headquarters located in other regions	It measures the average distance that each node is from all other nodes in the network	It measures the number of shortest paths in a network that traverse through that node	It measures the importance of a node in a network, based on the importance of its direct neighbours
Unit of measurement	Rank between 0 and 1				
Definition of ICT dimension	Based on NACE Rev. 2				
Unit of observation	NUTS 3 for EU and TL3 for the remaining OECD countries				
Source	9.7 Company-level information: ORBIS by Bureau Van **Dijk** (see Section 0)				
Reference year(s) considered	2008				

.8. Annex II: Composite indicators

The selected 42 indicators, their measurement and the resulting multiple rankings of 1,303 regions represent an abundance and diversity of information that seems impossible to analyse at first sight. In order to provide synthetised comparable results for further analysis and interpretation, the information contained in individual indicators has been aggregated, constructing a final composite EIPE indicator.

8.1 Normalization and rescaling of data

Most indicators are incommensurate with others, and have different measurement units. For example, the number of patent application is expressed per capita, while the share of ICT R&D centers owned by companies from a region and located abroad is expressed as a percentage of the total number of R&D centers owned by companies from a region.

To deal with this problem, indicators must be made comparable by bringing them to the same measurement scale, by transforming them into pure, dimensionless, numbers (OECD-JRC 2008). This is the normalization process.

Normalization process

In order to normalise the data used in this study, a standardization method, i.e. z-scores, is used. This method is the most commonly used because it converts all indicators to a common scale with an average of 0 and a standard deviation of 1 (EC-JRC 2005). The average of zero means that it avoids introducing aggregation distortions stemming from differences in indicators averages. The scaling factor is the standard deviation of the indicator across the units of observation, i.e. in the context of the current study of 1,303 NUTS 3 regions.[83]

In a more formal way, the normalized score of a raw score *x* is

$$z = \frac{x - \mu}{\delta}. \tag{2}$$

where μ is the mean of observations across the regions and σ is the standard deviation across the regions. The quantity *z* represents the distance between the raw score and the mean population in units of the standard deviation.

The advantage of z-scores over other normalisation methods is that an indicator with extreme values will have intrinsically a greater effect on the composite indicator. This behaviour is desirable in the current study, as there is an intention to reward exceptional performance, i.e. above average results on few indicators is considered of higher value than average performance on many indicators.

Rescaling process

In the next steps, the normalized scores are further rescaled in order to avoid negative scores and to ensure the incorporation of the indicators variability in the results. This is done through the *minmax* rescaling procedure, whose formula is:

$$Nx_{rj} = \frac{x_{rj} - x_{j,\min}}{x_{j,\max} - x_{j,\min}} \times 100. \tag{3}$$

where Nx_{rj} is the normalised and rescaled value of indicator *j* in the territorial unit *r*, x_{rj} is the normalised raw value of indicator *j* in the territorial unit *r*, $x_{j,\min}$ and $x_{j,\max}$ are the minimum and maximum values of indicator *j*.

[83] The intermediate results, i.e. the production of rankings for individual indicators, is done only for regions with indicator value greater than 0.

This method has found its way into a number of policy-oriented projects. For example, z-scores are used for the two composite indicators of the knowledge-based economy, published by the European Commission on Key Figures 2003-2004, for the environmental sustainability index developed at Yale University, and for the internal market index 2002 (EC-JRC 2005).

8.2 European ICT Poles of Excellence Composite Indicator (EIPE CI)

An EIPE Composite Indicator (CI) is formed by compiling individual indicators into a single index, on the basis of an underlying model of the multi-dimensional concept that was introduced by in the EIPE Report 2 (De Prato and Nepelski 2013a).

An important issue related to the construction of composite indicators is the one of weighting. Unfortunately, no agreed methodology exists to weight individual indicators (EC-JRC 2005). In particular the context of the current study does not make the choice of a weighting scheme easy, as there is no theoretical framework that would say which indicator should be more influential than others. Considering this, equal weighting is given to the indicators to construct composite indicators.

The EIPE CI is composed of all indicators. Its construction is done in two steps. In a first step, composite sub-indicators are created, one for each of the activities: R&D, Innovation and Business. Three intermediate sub-indicators are organized along the three activities, i.e.:

- **R&D sub-indicator** (R&D CI) comprises all relevant indicators included in Section 0 normalized and equally weighted.
- **Innovation sub-indicator** (Innovation CI) comprises all relevant indicators included in Section 0normalized and equally weighted.
- **Business sub-indicator** (Business CI) comprises all relevant indicators included in Section 0 normalized and equally weighted.

For the sake of using the same scale, the values of the three sub-indicators are standardized with the MiniMax procedure, in order to present them on a scale from 0 to 100.

In the second step, all information is synthesised in one final EIPE CI by aggregating the values of the three earlier sub-indicators in this final one. Thus, sub-indicators values are equally weighted, i.e. each with 33% weight. As above, in order to present EIPE CI on a scale from 0 to 100, the values are standardized with the MiniMax procedure.

9. Annex III: Data Sources

The following eight databases have been the primary data sources used to elaborate the indicators and measurements of EIPE:

1. QS World University Rankings by QS,
2. FP7 database by EC DG Connect,
3. Bibliometrics: Web of Science by Thomson Reuters,
4. ICT R&D centres locations: Design Activity Tool by IHS iSuppli,
5. European Investment Monitor by Ernst & Young,
6. Patent data: REGPAT by OECD,
7. Company level information: ORBIS by Bureau Van Dijk,
8. Venture Capital: Venture Source by Dow Jones.

In the following sections, each of the data source is described.

9.1 QS World University Rankings by QS

The rankings of Universities and Computer Science and Electronic Faculties originate from the QS World University Rankings®. It was formed in 2008 to meet the increasing public interest in comparative data on universities and organisations, and the growing demand for institutions to develop deeper insight into their competitive environment.[84]

The QS World University Rankings® currently considers over 2,000 universities in the world and evaluates over 700 of them, ranking the top 400. This list is used to build an indicator of the location of a ranked university in a region within the current project.

In addition, due to the fact the QS ranking includes 52 subject disciplines, one of which is Computer Science, additional faculty-level information is extracted for the purpose of the EIPE study.

To construct measures of faculty performance, the EIPE study used QS proprietary datasets to investigate its subject area at three levels, namely academic and employer reputation surveys and the Scopus data for the Citations per Faculty indicator. In detail, each of the faculty ranking pieces can be described in the following way:

- The **Academic reputation** survey is the centrepiece of the QS World University Rankings® since their inception in 2004. In 2010, it drew upon over 15,000 respondents to compile the results. In the survey, respondents are asked to identify the countries, regions and faculty areas that they have most familiarity with and up to two narrower subject disciplines in which they consider themselves expert. For each of the faculty areas they identify, respondents are asked to list up to ten domestic and thirty international institutions that they consider excellent for research in the given area. They are not able to select their own institution. The analysis places more emphasis on an international reputation than a domestic one – domestic responses are individually weighted at half the influence of international responses. This is a global exercise and recognizes institutions that have an international influence in these disciplines. Weightings are also applied to balance the representation by region.
- The **Employer reputation** survey considers the students' employability as a key factor in the evaluation of international universities and in 2010 drew on over 5,000 respondents to compile the results for the overall rankings. The employer survey works on a similar basis to the academic one only without the channelling for different faculty areas. Employers are asked to identify up to ten domestic and thirty international institutions they consider

[84] More information under: http://www.topuniversities.com (last accessed 01.02.2012)

excellent for the recruitment of graduates. They are also asked to identify from which disciplines they prefer to recruit. From examining where these two questions intersect, a measure of excellence in the given discipline is inferred. Employers seeking graduates from any discipline are weighted at 0.1 and those from a parent category (i.e. Social Sciences) are weighted at 0.25 relative to the weight of a direct response for the subject area. This analysis also places more emphasis on an international reputation than a domestic one, with domestic responses carrying half the weighting of international responses.

- **Citations per faculty** takes into account the size of an institution, and also observes its penetration into the global research landscape. The data for citations originate from Scopus by Elsevier E.V.[85] Papers in Scopus are tagged with an ASJC (All Science Journal Classification) code which identifies the principal foci of the journal in which they were published. When aggregated, these totals per faculty and their associated citations provide an indicator of volume and quality of output in the given discipline.

The main reason why this data source was selected for EIPE is that, in addition to the university ranking, it also offers the rankings described above by teaching subject, including Computer Science. This information allows us to observe the location of research and education in ICT activities at world- level.

This data source, though carefully selected from a range of data sources pursuing similar purposes, shows some limitations. The main constraint is that it offers only a limited number of universities, which does not allow us to cover the entire population of the European higher education institutions.

9.2 ICT FP7 funding: FP7 database by EC DG Connect

The Framework Programmes for Research and Technological Development, also called Framework Programmes or abbreviated to FP1, through to FP7, are funding programmes created by the European Union in order to support and encourage research in the European Research Area (ERA). FP7 spans through the period 2007 - 2013.

The analysis of the Framework Programme 7 programmes and participants is based on the database provided by DG Connect in November 2011 (and hence covers the period 2007-11). It is not available publically. In the current report, information on FP7 is used and concerns only the Information and Communication Technology (ICT) areas. The list of instruments through which projects were financed includes: CSA-ERA-PLUS, CSA-CA, CP-SICA-INFSO, CP-FP-INFSO-FET, CSA-SA, CP-IP, NoE, CP-CSA, CP-IP-INFSO-FET, CP-FP-INFSO, CP-FP, CSA-SA-INFSO-FET and CSA-CA-INFSO-FET.

The main reasons why this data source was selected for EIPE is that it offers a proxy for public R&D expenditures in ICT and allows us to observe the location of the R&D activity in ICT.

This data source, though carefully selected, shows some limitations. The main constraint is that it offers only a limited snapshot of EU-level publicly-financed ICT R&D in Europe. In particular, it does not cover national and regional expenditures in ICT R&D.

9.3 Bibliometrics: Web of Science by Thomson Reuters

The Web of Science is an online academic citation index provided by Thomson Reuters. It is designed to provide access to multiple databases, cross-disciplinary research, and in-depth exploration of specialized subfields within an academic or scientific discipline. As a citation index, any cited paper will lead to any other literature (book, academic journal, proceedings, etc.) which currently cites this work, or has done so in the past. In addition, literature which shows the greatest impact in a field covered by the Web of Science, or more than one discipline, can be selectively obtained. For example, a paper's influence can be determined by linking to all the other papers that have cited it. In this way, current trends, patterns, and emerging fields of research can be assessed. The Web of Science has indexing coverage from 1900 to the present.

[85] More information under http://www.scopus.com (last accessed 01.02.2012).

Regarding its scope, the Web of Science encompasses over 11,000 journals selected on the basis of impact evaluations. This selection includes open-access journals and over 12,000 conferences each year (2009), spanning multiple academic disciplines. Coverage includes the sciences, social sciences, arts, and humanities, and it is also cross disciplinary. For the purpose of the EIPE exercise, journals classified in the Computer Science research area are considered.

The main reason why this data source was selected for EIPE is that it offers a comprehensive overview of scientific output throughout the world divided into individual research areas, which permits the inclusion of EIPE-relevant fields such as Computer Science. This information allows us to observe the location of ICT R&D activity.

This data source, though carefully selected from a range of data sources pursuing similar purposes, has some limitations. The main constraint is that it offers only limited possibilities with respect to the extraction of information at the level of, for example, authors. Instead, only aggregation of information at the institutional level is possible.

9.4 ICT R&D centre location: Design Activity Tool by IHS iSuppli

The data used for the purpose of identification of ICT R&D centre locations originates from the 2011 IHS iSuppli database, a company-level dataset dedicated to observing the internationalization of R&D. It includes a list of R&D centers belonging to a number of high-tech companies together with their exact location, and additional information on the type of R&D activity performed in these centers.

The data on R&D locations is collected by IHS iSuppli, an industry consultancy,[86] to map R&D locations and activities of companies considered to be the major semiconductor influencers, i.e. the main users of semiconductors or, in other words the largest manufacturers of applied electronic and microelectronic products.

In order to check how representative the sample is, we compared it to the R&D Scoreboard, a list of the top 2,000 R&D investors in Europe and the rest of the world,[87] and also with the list of companies filing their patents at the USPTO. The results revealed that the firms contained in the dataset represent nearly 30% of the 2008 R&D budget of all companies included in the R&D Scoreboard and more than 30% of all patent applications filed to the USPTO in 2009. This way we are assured that the sample is representative for the population of large high-tech multinational firms.

The main reason why this data source was selected for EIPE is that it offers relatively detailed unique information on the location and ownership of ICT R&D centres worldwide. This information allows us to observe the location of ICT R&D activities.

This data source, though carefully selected from a range of data sources pursuing similar purposes, shows some limitations. For example, the characteristics of the dataset do not allow the building of time series. Also, the information available from this data source concentrates on the number of R&D Centers, their ownership and location, as detailed information on employment or R&D expenditures in those centres is not available at this level of granularity.

9.5 European Investment Monitor by Ernst & Young

The European Investment Monitor (EIM) is a unique monitor of foreign investment in Europe by companies from all over the world, but excludes investments in their home countries. Since 1997, data has been collected from all European countries and is published on a quarterly basis. As of 2011, it included over 40,000 observations.

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[86] More information under: http://www.isuppli.com (last accessed 01.02.2012)

[87] More information under: http://iri.jrc.ec.europa.eu/research/scoreboard_2010.htm (last accessed 01.02.2012)

The EIM is recognized as a comprehensive industry standard, tracking investment projects across Europe. It is a business information tool used by both professionals involved in corporate location strategy and inward investment issues and academic researchers (De La Tour et al. 2011). It is a benchmark for government and private sector organizations wishing to identify trends in jobs and industries, business and investment.

The EIM identifies the project-based foreign inward investment announcements that are new, expanding, or co-located in an international context.[88] When the consulting group discovers a new project, they track it in order to determine its exact location at the city level. Only investments where at least 10 jobs are created are considered.

The basic description of each investment project described by the EIM data includes the name of the firm, the parent company name, the name and the origin country of the parent company, the sector and both the country and the city of location. It also includes the function of each investment (unit of production and different service activities, such as headquarters, research and development centers, logistics, or sales and marketing offices).

The data collected by the EIM enables to:

- Review developments and movements in the inward investment marketplace, identify emerging sectors, industries and clusters,
- Benchmark regions and develop location strategies,
- Undertake in-depth, wide-ranging data analysis; for example: Which is Europe's most popular location for headquarters investments? What is the scale and nature of investment from South Korea? Or what is Germany's market share of pharmaceutical investment?

The main reason why this data source was selected for EIPE is that it offers detailed unique information on new investments in Europe and, due to the sector information included in the description, it permits the retrieval of ICT-specific investments. This information gives us a proxy for the dynamics of business activity in ICT.

This data source, though carefully selected from a range of data sources pursuing similar purposes, has some limitations. For example, as the EIM relies on data collection from the media, the main advantage of this source of information, i.e. being up-to-data and the speed of the information provision, can also be a disadvantage. This is related to the fact that not all investments are reported by the media and, hence, they will not be available from this source to the EIM.

9.6 Patent data: REGPAT by OECD

The OECD REGPAT database stores patent data, based on patent applications to the EPO and PCT filings, linked to more than 5 500 regions using the inventors/applicants addresses. This information has been linked to NUTS3 regions according to the addresses of the applicants and inventors. The data have been regionalised at a very detailed level so that more than 2 000 regions are covered across OECD countries. The selection of ICT patents follows the definition by OECD (OECD 2008).

When compiling or analysing indicators with regionalised patents, it is necessary to have some characteristics of patents and some rules in mind, so as to make the best use of the information and not misinterpret the indicators. The data from the REGPAT database, are constructed along the following principles:

- *Inventor v. owner region*: Patent data can be regionalised on the basis of the address of either the inventor or the holder. The inventor's address usually indicates where the

[88] The EIM excludes mergers and acquisitions or joint ventures (unless these result in new facilities, new jobs created), licence agreements, retail and leisure facilities, hotels and real estate investments, utility facilities including telecommunications networks, airports, ports or other, fixed infrastructure investments, extraction activities (ores, minerals or fuels), portfolio investments (i.e. pensions, insurance and financial funds), factory / production replacement investments (e.g. a new machine replacing an old one, but not creating any new employment), not-for-profit organisations.

invention was made, while the owner's address indicates where the holder has its headquarters. These two concepts have obviously different economic interpretations, especially as many patents are filed by large companies with several establishments located in different regions and countries.

- *Fractional v. whole counting*: Patents usually have several inventors and can have several owners. When regionalising patents, a patent with, say, inventors in two regions can be either attributed wholly to the two regions, or shared (with a total of shares of 100%) between the two regions. As a significant proportion of patents have inventors from different regions it is important to specify what rule is used, and when one is better, to use it. For instance, when comparing the performance of regions it is recommended to use fractional accounting, which i) attributes to each region its actual contribution to the invention; ii) when summed over all regions gives a total of 100%. On the other hand, when compiling an indicator like *share of patents with co-inventors from another region*, the use of whole counting, both at the numerator and the denominator, is recommended.
- *Priority year*: This is the year of first filing for a patent. It is the closest to the actual date of invention, and should therefore be used as the reference date when compiling patent indicators which aim to reflect technological achievements. Other dates, e.g. follow-up application, publication or grant, are dependent on administrative procedures and can be one to ten years after the invention and thus misleading when interpreting the data.

The methodology developed to identify regions on the basis of the addresses of patent inventors consists of an iterative procedure that matches postal codes and/or town names, identified in the addresses, with regions using a set of lookup tables (such as a postal code - NUTS3 correspondence).

The main reason why this data source was selected for EIPE is that it offers unique information on patenting activity at regional level across a number of countries, which allows us to extract information on ICT innovation activity at NUTS 3 level. The EIPE study uses this information as a proxy for innovative activity in ICT.

This data source, though carefully selected, shows some limitations, which, if not taken into account, can affect the results of the EIPE project or their interpretation. For example, REGPAT relies on the EPO and PCT filings, which considerably limits the number of patents that are considered.

9.7 Company-level information: ORBIS by Bureau Van Dijk

Company-level information is taken from the ORBIS database by Bureau Van Dijk. It contains comprehensive information on companies worldwide.

In order to meet the requirements of the EIPE project, while constructing the indicators on the number of employees, turnover, intangible and R&D expenditures at the NUTS 3 level, the following criteria were applied:

- Geographic coverage: EU 27;
- The ICT industry was defined according to the NACE Rev 2 definition of the ICT sector (OECD 2007);
- Company status: Active companies;
- Type of entities: Industrial companies
- In order to avoid double-counting, separate searches were run using a filter on consolidation code. First, companies with consolidated accounts only and then companies with unconsolidated accounts only were selected.
- Time coverage between 2005 and 2011, the last available date.

Besides providing the company-level information that was used to count the number of firms or the employment, ORBIS was also used to map the organizational structure of the main ICT R&D

investors by including their affiliates. This allowed to observe the internationalisation of ICT business activities and to construct the ICT business network.

In addition, the information on the location of business affiliates owned by companies belonging to the ICT Scoreboard and the location of their respective Headquarters originates from the Orbis database. The analysis presented in this report is based on company data from the 2009 EU industrial R&D Scoreboard 3 (henceforth the Scoreboard) in which R&D investment data, and economic and financial data from the last four financial years are presented for the 1,000 largest EU and 1,000 largest non-EU R&D investors in 2008. The Scoreboard covers about 80% of all company R&D investments worldwide. From the Scoreboard, we have extracted the sub-set of ICT sector companies, which we refer to in this report as the ICT Scoreboard. This dataset serves for the following analysis that aims to benchmark R&D investments of EU ICT companies against those of non-EU companies.

The construction of the ICT Scoreboard dataset followed two steps, which were carried out at IPTS as part of a larger project. First, the ICT sample was selected from the European R&D Investment Scoreboard 2009 and then it was merged with the BvD Orbis database.

The R&D Scoreboard collects information on R&D investment, sales, operating surplus, employment and capital expenditure (to be interpreted as a flow, the increasing of tangible assets) for the top 1,000 European groups and top 1,000 non-European groups, ranked according to the amount of nominal R&D investment. The period covered includes the four years from 2005 to 2008.

The merge with the database Orbis was done in order to collect the information on the individual shareholders that have relevant participations in group headquarters. We used a standard rule of thumb of direct or indirect share above 20%. As a result, in our database, the individual observation is a group, for which we have the R&D Scoreboard information together with information on up to a potential maximum of five shareholders, with their legal entity and details of the amount of shares. The ownership threshold was set at the level of 50.1%.

The main reason why this data source was selected for EIPE is that it offers unique and standardized information on company-level information for the ICT sector that can be regionalised and presented at the NUTS 3 level. This information offers a proxy for the economic and, to some extent, the innovative activity of ICT companies.

This data source, though carefully selected from a range of data sources pursuing similar purposes, has some limitations. The most important limitation is the geographical coverage and the incompleteness of the data collected. In addition, there are significant problems concerning the extraction of detailed information, e.g. on a firm's ownership structure.

9.8 Venture capital: VentureSource by Dow Jones

Dow Jones VentureSource provides comprehensive data on venture capital-backed and private equity-backed companies – including their investors and executives – in every region, industry sector and stage of development throughout the world.

According to Kaplan et al. (2002), who provide a detailed overview of this database and compare it with Venture Economics (an alternative source of information), the VentureSource data are generally more reliable, more complete, and less biased.

This database contains information on venture capital transactions, the financed companies and the financing firms. The data are largely self-reported by venture capital firms, but the database conducted several plausibility checks.

The selection of ICT companies was based on Dow Jones classifications and includes companies belonging to the following industry segments: Communications & Networks, Electronics & Computers, Information Services, Semiconductors, Software and Other IT.

This data source was selected for EIPE because it offers unique and standardized information on venture capital deals with all the detailed information concerning the financed and financing

entities. In addition, it allows us to select deals that concern the ICT sector. This information can be used as a proxy for the funding of innovative products, particularly those in the commercialisation phase, and companies.

This data source, though carefully selected from a range of data sources pursuing similar purposes, has some limitations. VentureSource relies on the voluntary information provision by Venture Capital funds and companies. Thus, despite being up-to-date, there is no guarantee that it covers the entire universe of venture capital.

10. Annex IV: Definition and characteristics of a network structure

A network consists of a graph whose elements include two sets: set of nodes (vertices), that correspond to the selected unit of observation, and a set of lines or relationships, that represent relations between units. Relationships relevant in the context of the EIPE project are between regions. A line can be directed – an arc, or undirected – an edge. In a formal way, a network

$$N = (V,L,W,P) \tag{4}$$

consists of a graph $G = (V, L)$, where V is the set of nodes, A is the set of arcs, if the lines are directed, and E is the set of edges, if the lines are not directed, and $L = E \cup A$ is the set of lines. Additional information on the lines is given by the line value function W and on nodes by the value function P.

Regarding the structural properties of a network, the **density of a network** is, among others, a key indicator providing information about the network structure. The density of a network is the number of edges that is expressed as a proportion of the maximum possible number of connections. It is formally defined as

$$\lambda = \frac{m}{m_{\max}} \tag{5}$$

where $m_{\max}$ is the total number of lines in a complete network, i.e. a network where all the nodes are connected to each other, given the same number of nodes.

In order to obtain further information on the structure of a network it is worthwhile to analyse **network centrality**. Centrality is an important concept in studying networks (Freeman 1978). In conceptual terms, centrality measures how central an individual is positioned in a network. The most obvious way of capturing degree centrality of V_i is counting the number of its neighbours, i.e. its degree. The way to compute degree centrality is to count the number of nodes connected to V_i, i.e.:

$$C_i^d = \frac{d}{V-1} \tag{6}$$

If there is no information on the direction of edges, i.e. an un-directed network, the measurement of a node's position can be measured by the total number of connections with the node. Then, **a node's degree** is defined as:

$$k_i \equiv \sum_{j \neq i} a_{ij} \tag{7}$$

If there is information on the direction of edges, i.e. directed network, the measurement of a node's position can be disaggregated to account for the incoming and outgoing connections to and from the node. Then, **the in-degree and out-degree** are defined as:

$$k_i^{in} \equiv \sum_{j \neq i} a_{ij} \tag{8}$$

$$k_i^{out} \equiv \sum_{j \neq i} a_{ji} \tag{9}$$

where a_{ij} represents the directed link from V_i to V_j and a_{ji} the reverse relationship.

In order to cast more light on the intensity of interactions, the degree measures can be replaced by node strength capturing the sum of weights given to the connections to any V_i. Similarly to the

degree measures, it is possible to capture the intensity of incoming and outgoing connections to and from a vertex. Thus, in a formal way **in- and out-strength** are defined as:

$$s_i^{in} \equiv \sum_{j \neq i} w_{ij} \tag{10}$$

$$s_i^{out} \equiv \sum_{j \neq i} w_{ji} \tag{11}$$

where w_{ij} represent the intensity of the directed link from V_i to V_j and w_{ji} the reverse relationship (Squartini et al. 2011).

Nodes' centralities in a network can have large or small variance. On the one hand, a network, where few actors have much higher centrality than other actors is said to be strongly centralised. A typical example is a star network. On the other hand, if unit centrality measures have small variance, the centralisation of a network is low. Thus, in order to assess the level of **centralisation of the network**, we use a network degree centralisation defined as

$$C^d = \frac{\sum_{i=1}^{n} | C_i^d - C_i^{d*} |}{(n-2)(n-1)}, \tag{12}$$

where C_i^{d*} is the highest value of centrality measure in the set of units of a network (Freeman 1978). Network centralisation index can take any value between 0, if all units have equal centrality value (cycle graph), and 1, if one unit completely dominates all other units (star graph).

Except for the degree centrality defined in (6), within graph theory and network analysis, there are a number of other measures of the centrality of a vertex within a graph that show the relative importance of a vertex within the graph (Koschützki et al. 2005). In this we use of two additional most commonly applied measures, i.e. closeness centrality and betweenness centrality.

The closeness centrality of node *i* is the number of the remaining nodes divided by the sum of all distances between that node and all the remaining ones, i.e.:

$$C_i^c = \frac{n-1}{\sum_{j \neq i}^{n-1} \partial_{ij}}. \tag{13}$$

At the aggregate level, **centrality closeness of a network** is defined as:

$$C^c = \frac{\sum_{i=1}^{n} | C_i^c - C_i^{c*} |}{(n-2)(n-1)/(2n-3)}, \tag{14}$$

where C_i^{c*} is the highest value of closeness centrality measure in the set of units of a network (Freeman 1978). The index takes values between 0 and 1, whereas the closeness centrality of a star network is 1.

The betweenness centrality of a node is the proportion of all geodesics distances between pairs of other nodes that include this vertex. Formally, the betweenness centrality of V_i can be expressed as:

$$C_i^b = \sum_{j \neq k} \frac{\partial_{jk}^i}{\partial_{jk}}, \tag{15}$$

where ∂_{jk} is the total number of shortest paths joining any two nodes V_k and V_j, and ∂_{jk}^i is the number of those paths that not only connect V_k and V_j, but also pass through V_i. The betweenness centrality of each node is a number between 0 and 1. This property of a network reflects the

amount of control that a node exerts over the interactions of other nodes in the network (Yoon et al. 2006). The measure of betweenness centrality rewards nodes that are part of communities, rather than nodes that lie inside a community. Betweenness centrality reflects the shortest path between two others. Therefore, it can be regarded as a measure of gatekeeping and is considered to be a measure of strategic advantage and information control.

Similarly, the **network betweenness centralization measure** can be defined as:

$$C^b = \frac{\sum_{i=1}^{n} | C_i^b - C_i^{b*} |}{(n-1)}, \tag{16}$$

where C_i^{b*} is the highest value of betweenness measure among all nodes. This measure compares the variance of betweenness centrality in a network and takes as a reference a star graph (C^b =1). In such a graph, the node in the middle holds the highest betweenness centrality, i.e. a strategic position and the graph is highly unequal or highly centralized.

Further measure of a node's position in the network used in this study is **eigenvector centrality** and relates to the quality of a node's connections and is. It assigns relative scores to all nodes in the network based on the principle that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes. Google's PageRank is a variant of the Eigenvector centrality measure (Spizzirri 2011).

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European Commission
EUR 26428 – Joint Research Centre – Institute for Prospective Technological Studies

Title: Analysing the European ICT Poles of Excellence: Case Studies of Inner London East, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn

Authors: Daniel Nepelski, Giuditta De Prato

Luxembourg: Publications Office of the European Union

2014 – 189 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online)

ISBN 978-92-79-35066-5 (pdf)

doi:10.2791/63309

Abstract
The EIPE project aims to identify activities related to ICT R&D and innovation which are geographically concentrated and which demonstrate high performance: the European ICT Poles of Excellence. Besides providing a comprehensive map of ICT-related activity in Europe, the project looks at five NUTS3 regions that can be considered as key elements of the European ICT landscape, i.e. Inner London East, Paris, Kreisfreie Stadt Darmstadt, Dublin and Byen Kobenhavn. The study identifies the strengths and weaknesses of each place and provides an overview of policy measures that were undertaken in each of them to facilitate the development of ICT R&D, innovation and business activities.

LF-NA-26428-EN-N

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Publications Office

doi:10.2791/63309
ISBN 978-92-79-35066-5 (pdf)