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Explaining the Spatial Pattern of Knowledge Intensive Business Services: the Role of Internet Infrastructure

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Summary

There is a widespread discussion regarding the role of information and communication technologies (ICTs) in the era of digital economy. Though, the question how these technologies are related to the economic activities in space, is not answered fully yet. Partially, it is conditioned by the invisible and complex nature of ICTs, which is hard to deconstruct and even harder to explore. What is obvious is that those technologies are not evenly distributed and equally accessible to everyone – not all people, places and businesses benefit equally from the advantages that those technologies generate (Tranos and Mack, 2015). Hence, if those technologies create comparative advantages to places through increasing digital accessibility (Tranos, Reggiani, et al., 2013) the lack of those technologies might cause respective results.

The importance of internet's physical infrastructure is well noted by policy makers. Aiming to foster the network-based knowledge economy and growth in Europe, the Digital Agenda for Europe (DAE) was adopted in 2010 with the specific broadband coverage goals, which is acknowledged as priority at all policy levels of Europe:

- Universal broadband coverage by 2013, which was already achieved in 2013 mainly (96.1%) through fixed technologies

Universal broadband coverage of speeds at least 30mbps, and penetration of ultra-fast broadband (above 100mbps) in 50% of European households for 2020. These speeds are achieved through Next Generation Access (NGA) coverage (Soldi, Cavallini, et al., 2016, Valdani Vicari & Associati and IHS Inc., 2015, Point Topic, 2012).

The developmental role of ICTs at regional level also a subject of interest for researchers. This study tries to determine the comparative importance of broadband coverage (as main part of ICTs) for knowledge intensive business services in European regions. The Knowledge intensive business services are also subject of increasing interest of both, scholars and policy makers intending to foster a knowledge-based economy.

The study uses spatial analysis techniques to understand the comparative importance of broadband coverage for knowledge intensive business services. The results suggest that there is no homogeneous impact of internet's physical infrastructure on KI(B)S – the comparative importance of broadband is different for Eastern, Western, Southern and Northern Europe depending on the region-specific characteristics, such as absorptive capacity of a region. The results of the study also revealed the higher importance of advanced broadband technologies in comparison with the standard ones. It is an important implication for policy makers as well, who might emphasize to improve the NGA technologies coverage at regional level.

Keywords

Internet Infrastructure, Broadband, Knowledge Intensive Business Services, Spatial pattern, spatial analysis techniques, Moran's I

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Abbreviations

IHS	Institute for Housing and Urban Development
NGA	Next Generation Access broadband coverage
KI(B)S	Knowledge intensive (business) Services
ICT	Information and Communication technologies
SAR	Spatial Autoregressive Model
SEM	Spatial Error Model

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Chapter 1: Introduction

1.1.2 Background

Knowledge intensive services, and, particularly, Knowledge-intensive business services (KIBS) are one of the fastest growing sectors of economy, attracting increasing interest of researchers and policy makers during last 15-20 years. The concern about these sectors is related to the intention of western economies and the European Union to become knowledge-based economies (Miles, 2003, European Commission, 2012). These sectors provide considerable potential for employment and growth and, in many cases, the development of them in a region can be considered as an indicator of transition from industrial economy to knowledge-based one. Moreover, KI(B)S firms are crucially important for innovation as they often play roles of knowledge carriers, producers and mediators in national and regional economics. (Tödtling, Lehner, et al., 2006, Miles, Kastrinos, et al., 1995a, Strambach, 2008, Miles, 2003).

The increasing importance of KI(B)S attracted the interest of researchers and policy makers towards the spatial pattern of these services across European regions. As illustrated on the figures #1 and #2, these sectors show notable differences among regions in terms of spatial concentration (European Commission, 2012). Some authors suggest that the location decision of KI(B)S is related to groups of factors, such as localization and urbanisation externalities, backward and forward linkages - region-specific sectoral structure determining the intermediate demand on those services (Meliciani and Savona, 2015). On the other hand it is also argued that KI(B)S , which are intensive users of ICT, are more likely to be footloose in terms of choosing location as they deal with intangible knowledge and knowledge-based products (Tranos and Mack, 2015).

There are mainly three school of thoughts regarding the impact of ICTs on firms location: concentration, deconcentration and heterogeneous. The theories regarding concentration power of ICTs imply that the urban-bias of internet infrastructure will strengthen rather than mitigate the centripetal forces of cities (Gaspar and Glaeser, 1998, Grubesic and O'Kelly, 2002). The theories regarding the deconcentration power of ICTs suggest that these technologies will enable firms locate outside costly central urban areas and substitute the real face-to-face contact with virtual real-time interactions. The heterogeneous school of thoughts implies that the distribution pattern of ICTs is not homogeneous, thus the impact it generates is highly context-dependent, as well (Mack, 2014, Mack, Anselin, et al., 2011).

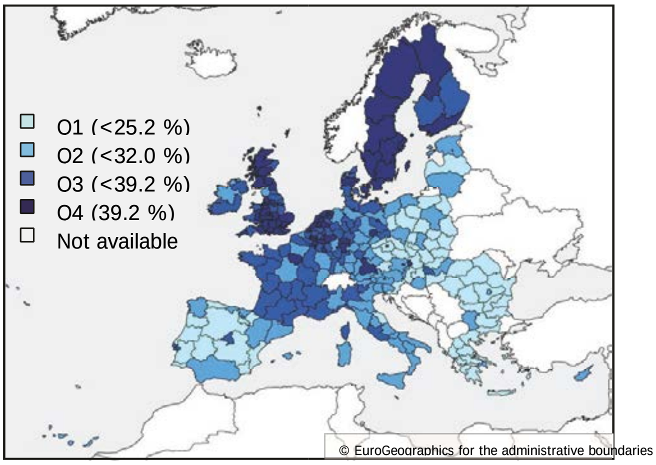

Figure 1: Share of KIS on total employment (Quartiles, 2007) . Source:(European Commission, 2012)

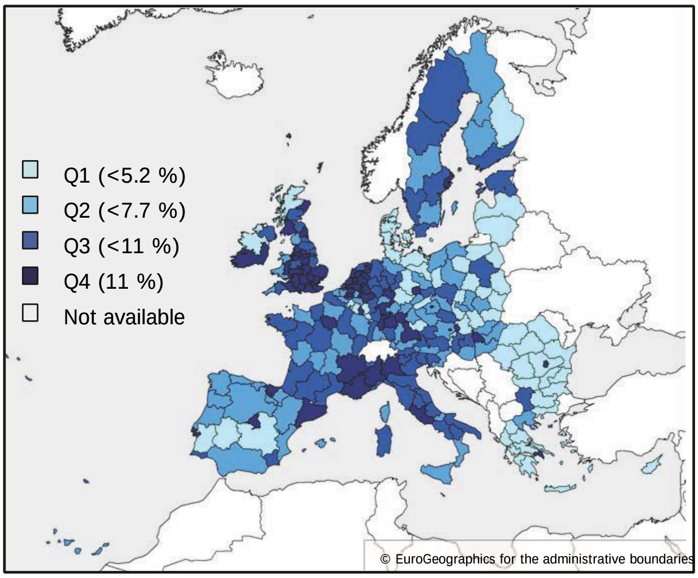

Figure 2: Share of KIBS on total employment (Quartiles, 2007). Source: (European Commission, 2012)

As main part of ICT, the internet infrastructure is considered to be the "supporting layer of the digital economy" (Tranos and Mack, 2015, p.2). It has been argued that the internet infrastructure facilitating connectedness of distant places should diminish the importance of location and lead to the "flat world" (Friedmann, 1986, Tranos and Mack, 2015). In fact, various studies suggest that the internet infrastructure is far from being evenly distributed and thus, the effect it generates, is also differentiated spatially (Tranos, 2012, Tranos, Reggiani, et al., 2013). Some authors even suggest that the concentration of internet's physical infrastructure might work as location factor endowment and affect the micro and macro level competitiveness of a place through providing better digital accessibility (DA) (Tranos, 2009, Tranos, Reggiani, et al., 2013). This factor is increasingly important for knowledge intensive sectors, which are highly dependent on premium quality any-time internet access (Tranos and Mack, 2015, Mack, 2014).

Aiming to foster the network-based knowledge economy and growth in Europe, the Digital Agenda for Europe (DAE) was adopted in 2010 with the specific broadband coverage goals, which is acknowledged as priority at all policy levels of Europe:

- Universal broadband coverage by 2013, which was already achieved in 2013 mainly (96.1%) through fixed technologies
- Universal broadband coverage of speeds at least 30mbps, and penetration of ultra-fast broadband (above 100mbps) in 50% of European households for 2020. These speeds are achieved through Next Generation Access (NGA) coverage (Soldi, Cavallini, et al., 2016, Valdani Vicari & Associati and IHS Inc., 2015, Point Topic, 2012)

To monitor the broadband coverage objectives progress, The Broadband Coverage in Europe project was launched. The annual reports measure the coverage of fixed and wireless broadband technologies at NUTS 3 level in EU countries and Iceland, Norway and Switzerland in addition to it. figure #1 shows the regional differences in Europe in terms of total standard fixed broadband coverage and NGA coverage for 2012 (Valdani Vicari & Associati and IHS Inc., 2015). The rural and remote regions are of particular interest (Soldi, Cavallini, et al., 2016).

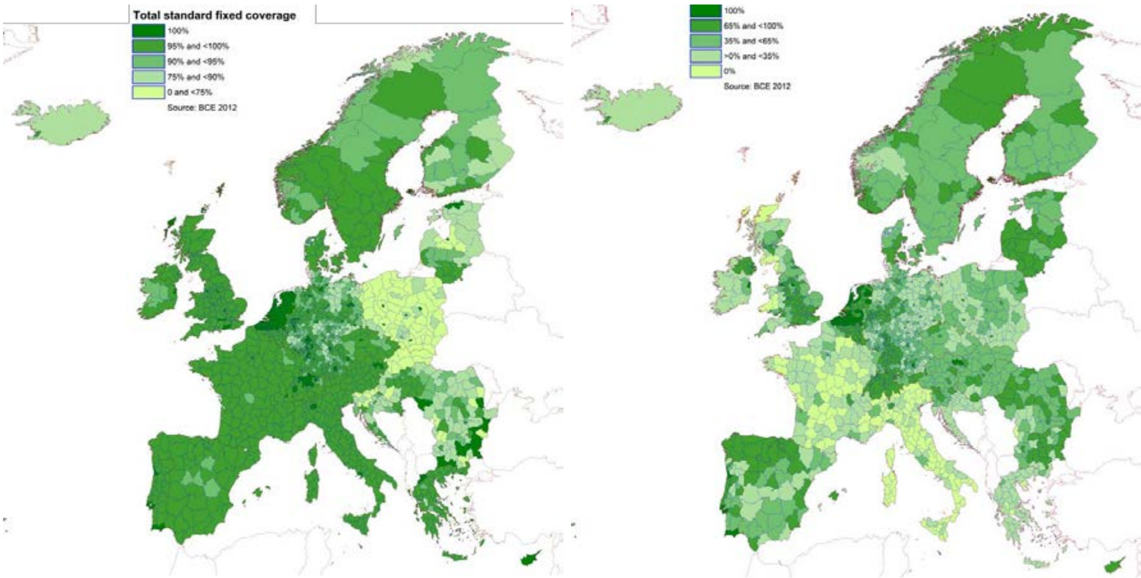

Figure 3: Standard fixed broadband and NGA coverage in the study countries. Source: (Point Topic, 2012)

1.1.3 Problem Statement

Various studies examined the connection between the level of broadband and Knowledge intensive business services in the USA, arguing that spatial disparities in broadband availability may impact the presence of and regional specialisation in knowledge intensive business service, as knowledge is the key input and output of their production which is transmitted by ICTs (Mack, 2014). The results of the studies over the US countries suggest that the impact of broadband on KIBS is heterogeneous. Broadband is an important factor that affects the development of places with good business climates considered previously too remote for knowledge intensive firms (Mack, 2014, Mack, Anselin, et al., 2011).

The results of the studies across the United States raised an issue to study the impact of broadband coverage on the spatial pattern of knowledge intensive business services in European regions. Taking into account the importance of ICTs for KI(B)S, it is important to analyse to what extent the broadband provision influences the level of concentration of KI(B)S in European regions.

1.1.4 Research Objectives

The main objective of the thesis is to examine the relative importance of broadband coverage to level of KI(B)S sector development across European regions.

There are three sub-objectives of the research:

The localization of business services, and particularly Knowledge intensive business services is dependent on various factors. “The classical sources of agglomeration economies, in particular localization and urbanization externalities; The role of intermediate demand, in particular the structure of intermediate linkages between BS and their manufacturing users and the region-specific sectoral structure; The region-specific innovation and knowledge infrastructure, particularly the ICT intensity” are the main determinants of regional specialization in business services, which are in fact the same as services labeled as knowledge intensive, according to the author (Meliciani and Savona, 2015, p.3). Human capital is crucially important for KI(BS) and the knowledge intensive firm locational decisions are often influenced by the availability of skilled labor pool

(European Commission, 2012). Derived from all above mentioned, the first sub-objective is to examine to what extent the level of broadband provision is related to the spatial pattern of KI(B)S while controlling for the other groups of factors for years 2011-2013.

The second sub-objective is to analyze the relationship between spatial patterns of broadband coverage and KI(B)S, i.e. examine whether the regional specialization in KI(B)S sector is spatially related to the level of broadband provision in European regions for 2014.

The third sub-objective is to examine whether the importance of broadband coverage in comparison with other groups of factors vary across sub-regions of Europe for the latest year available, i.e. whether the impact of internet infrastructure is heterogeneous or it is the same for all regions.

1.1.5 Provisional Research Question(s)

Main research question:

What is the comparative importance of broadband coverage to the level of KI(B)S sector development across European regions?

There are three sub-questions of the research:

To what extent the level of broadband provision is related to the spatial pattern of KI(B)S while controlling for the other groups of factors for years 2011-2013?

Is the regional specialization in KI(B)S sector spatially related to the level of broadband provision in European regions for 2014?

Does the comparative importance of broadband coverage for development of KI(B)S sector vary across sub-regions of Europe for 2014?

1.1.6 Significance of the Study

1.1.6.1 Scientific Relevance

The research aims to add knowledge to existing literature regarding the impact of broadband on Knowledge Intensive (Business) Services and contributes to better understanding whether and to what extent the spatial distribution of internet infrastructure explains the spatial concentration of Knowledge Intensive (Business) Services at regional level. The scientific relevance of the thesis is derived from following reasons.

Firstly, studies intensively discuss the impact ICTs on the economic growth (Tranos, 2012), productivity (Seo and Lee, 2006), knowledge economy, FDI inflow (Gholami, Sang-Yong, et al., 2006) etc. In most cases, the authors consider telephone landlines, mobile phone subscribers and internet users per thousand of population, binary linkages of backbone connection and bandwidth capacity of these connections, as proxies of ICT. This study aims to use broadband provision data, which indicates the infrastructural capital of a region in relation with the population – i.e. the actual infrastructure which is already there for households to subscribe the broadband services if they are willing to.

Secondly, as previous studies suggest, there is a spatial autocorrelation in the data of knowledge intensive business services and ICTs (Meliciani and Savona, 2015). Instead of using linear regression model, such as OLS, the study accounts for spatiality of variables and uses spatial models because presence of spatial autocorrelation in variables in linear models produces inconsistent estimators (when not including spatial lag of dependent variable) and unbiased but inefficient coefficient estimates when the spatial structure is present in the error term (Anselin, 1988, Mack, Anselin, et al., 2011). The third gap is the study area. The studies regarding the relationship between internet infrastructure and knowledge intensive establishments are done for the countries of United States. This study aims to analyse the relationship in European context as well.

1.1.6.1 Policy Relevance

The issue of competitiveness is becoming more and more important and policy makers are concerned about finding the determinants of regional competitive advantage. The level of ICT infrastructure within a region can be considered as one of them, while the lack or low level of this type of infrastructure might me a retaining factor for regional development (Mack, Anselin, et al., 2011). As mentioned above the study aims to contribute to better understanding the issue of whether and to what extent the spatial distribution of broadband technologies is related to the spatial pattern of knowledge intensive business services and thus, to what extent the policies, aiming to foster knowledge economy, should emphasize the issue of internet infrastructure development at regional or local level.

1.1.7 Scope and Limitations

1.1.7.1 Scope

The research aims to cover European regions, but at different regional level. The first research sub-question analysis uses NUTS 3 regions, which is smaller regional division used for specific diagnosis. The rest of the analysis is based on NUTS2 regions level data, as shown on the figure #2. The quantitative approach on European scale tries to determine to what extent the internet infrastructure distribution pattern is related to the spatial pattern of knowledge intensive business services at the level of European regions and what is the importance of broadband provision in comparison with other groups of factors.

Figure 4 GISCO administrative boundaries (NUTS 2), Source (European Environment Agency, 2012)

1.1.7.2 Limitations

The limitation for the analysis of 1s research question is the data of broadband coverage, which is extracted from annual reports (2011-2013) and is of ordinal scale instead of exact numbers. The second limitation is that the report series only contain two indicators – standard fixed broadband and Next Generation Access broadband coverage, which are combination of different technologies. The data for each technology separately exists, but is not available publicly. The data for KI(B)S contains some missing values, but not of considerable amount. The availability of some control variables, such as R&D expenditure as percentage of GDP, on NUTS 3 level is also an issue.

The next limitation is the data availability at NUTS 2 level for 2nd and following research sub-questions. Analysis at this level of regional division might be less precise then analysis at NUTS 3 level. At this level one can not capture the influence of an urban or metropolitan area, or proximity to it. The limitation of independent variable is almost the same as for previous research question: the broadband provision vary in terms of its availability, speed, technologies and market competition. High speed internet is delivered with various technologies described in the 2nd chapter in more details. While the research in the United States ((Mack, 2014) uses number of providers in specified area, such data is not available for Europe. Instead, two indicators are used for spatial analysis: indicator for availability of standard fixed or Next Generation Access technologies.

Chapter 2: Literature Review / Theory

2.1. Introduction

The structure of literature review is following: the knowledge intensive (business) services, the internet geography, and the relation between them. The part regarding Knowledge intensive (business) services defines the nature of them according to the literature, and tries to find the determinants of the spatial concentration of these services.

The study relies on previous studies in the US (Mack, 2014, Mack, Anselin, et al., 2011, Tranos and Mack, 2015) which consider the broadband provision as independent variable in relationship with KI(B)S. Though, the literature review contains the part regarding the geography of internet backbone network in order to fully understand the drivers of formation of internet infrastructure spatial pattern and the impact of unequal distribution of it on regions. "Global and local are mutually constitutive" – intra-urban and inter-urban networks are equally important and one can not function without the other (Rutherford, 2005a, p.2397). The last part of the literature review is dedicated to the relationship between internet infrastructure (broadband provision) and knowledge intensive business services, as intensive users of ICT.

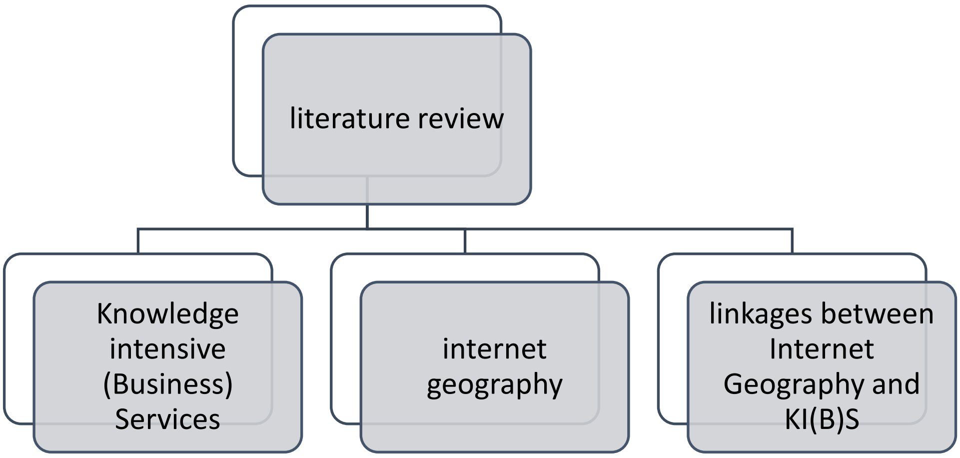

Figure 5: Structure of the Literature Review. Source: Author, 2016

2.1.1. Knowledge intensive (business) services

The literature uses Knowledge-intensive business services (KIBS) and knowledge intensive services interchangeably. In fact, both terms are used to describe services, "whose activities have a high knowledge component" (European Commission, 2012, p.6). The main characteristic of these firms – high knowledge intensity – is mainly measured by levels of staff with high professional qualifications and degrees.

Some KI(B)S are oriented to scientific and technological knowledge (identified as "technology-based KI(B)S" by some authors) and are important suppliers of innovation for their clients. They deal with problems related to computer hardware, software, telecommunications, IT, engineering, construction, transport infrastructure, research, laboratory testing. Other KI(B)S are oriented to other topics – marketing, legal, administrative, financial and so on (identified as traditional professional services by some authors (Consoli and Elche-Hortelano, 2010)). They are important contributors to organisational innovation as they deal with issues associated with systems and institutions, administration, inter-organisational activities and management, problems concerning social groups etc., but in many cases, traditional professional KI(B)S play important role as supporters for technological innovation as they develop capabilities in technology oriented fields to assist their clients. For example, many accounting or management consultancy firms provide IT consulting or financial advisors specialized in high-tech fields and provide rapid updates to their clients (Miles, 2003). In addition to the nature of services provided by them, the role of KI(B)S in innovative services vary as well: informative, diagnostic, advisory, facilitative, turnkey, and managerial (Miles, Kastrinos, et al., 1995a, Consoli and Elche-Hortelano, 2010, Windrum and Tomlinson, 1999, Hertog, 2000, Antonietti and Cainelli, 2008, Miles, 2003).

KI(B)S play important role as they not only create knowledge, but also develop human capital and provide knowledge generating services to other firms. These firms are crucial for knowledge distribution in regions, as their interaction with others through commercial relationships, unpaid interactions in learning process between actors and labour mobility, which is quite high in service sector, contributes knowledge spillover in regions. KIS play an important role to translate academic and scientific knowledge into something practical for applicable business world through market relationships (BISHOP, 2008)

Table 1: Definition of KIS and KIBS according to NACE rev. 1.1. Source: (European Commission, 2012)

KIS	**Knowledgeintensive hightech services**	Post and telecommunications (64) Computer and related activities (72) Research and development (73)
	Knowledgeintensive market services (excluding financial intermediation and high-tech services)	Water transport (61) Air transport (62) Real estate activities (70) Renting of machinery and equipment without operator, and of personal and household goods (71) Other business activities (74)
	Knowledge-intensive financial services	Financial intermediation, except insurance and pension funding (65) Insurance and pension funding, except compulsory social security (66) Activities auxiliary to financial intermediation (67)
	Other knowledge-intensive services	Education (80) Health and social work (85) Recreational, cultural and sporting activities (92)
KIBS	**Knowledge-intensive business services**	Computer and related activities (72) Research and development (73) Legal, technical and advertising (74.14)

Table 2. KIS classification according to Eurostat NACE Rev.2. Source: Author, based on (Eurostat, 2014)

KIS classification	NACE Rev.2 codes - 2-digit level between brackets
High-tech knowledge-intensive services	Motion picture, video and television programme production, sound recording and music publishing activities (59); Programming and broadcasting activities (60); Telecommunications (61); Computer programming, consultancy and related activities (62); Information service activities (63); Scientific research and development (72)
Knowledge-intensive market services (excluding financial intermediation and high-tech services)	Water transport (50); Air transport (51); Legal and accounting activities (69); Activities of head offices; management consultancy activities (70); Architectural and engineering activities; technical testing and analysis (71); Advertising and market research (73); Other professional, scientific and technical activities (74); Employment activities (78); Security and investigation activities (80)
Knowledge-intensive financial services	Financial service activities, except insurance and pension funding (64); Insurance, reinsurance and pension funding, except compulsory social security (65); Activities auxiliary to financial services and insurance activities (66)
Other knowledge-intensive services:	Publishing activities (58); Veterinary activities (75); Public administration and defence; compulsory social security (84); Education (85); Human health activities (86); Residential care activities (87); Social work activities without accommodation (88); Creative, arts and entertainment activities (90); Libraries, archives, museums and other cultural activities (91); Gambling and betting activities (92); Sports activities and amusement and recreation activities (93)

According to Eurostat NACE rev. 1.1. (Statistical classification of economic activities) Knowledge intensive services include knowledge intensive market services, financial services, business services and other services, as shown on the table 2. Though, more recent statistical classification defines KIS in a slightly different way as shown on the table 3. The services are aggregated into knowledge intensive services (KIS) and less knowledge-intensive services. The distinction is based on the share of tertiary educated persons in those services (Eurostat, 2016).

2.1.2. Determinants of Knowledge intensive (business) services growth

The importance of knowledge intensive (business) services increased during last 15-20 years. Service activities, in general, constitute a big part of the cost of most of the companies. Even for firms producing physical goods, i.e. manufacturing, the actual production of the physical goods takes 15-25% of the cots. The rest of the value added involves service activities, such as design, development, and distribution and so on. In some cases these services are provided internally by the companies, but the growth of knowledge requirements of customers increased the tendency of outsourcing by companies. It contributed to the emergence and rapid growth of business services, and knowledge intensive business services, in particular (Zieba, 2013, Antonietti and Cainelli, 2008, Miles, Kastrinos, et al., 1995a, Miles, 2003).

The literature distinguishes the factors that contributed the emergence and rapid growth of this sector:

- Outsourcing of services by client firms
- Increasing demand for high-standard technological knowledge, especially new technologies and IT
- Increasing demand and high requirements for specialised knowledge in social, administrative, and regulatory issues
- Growing importance of services and intangible products in the knowledge-based economy (European Monitoring Centre on Change, 2005).

2.1.3. Spatiality of Knowledge intensive (business) services

Innovation research during last decades showed that the innovative activities of business firms are influenced by regional factors and endowments resulting in formation of region-specific innovation modes and spatial differences over regions in terms of KI(B)S sector development. The process of regional concentration is self-reinforcing and further concentration is expected (European Commission, 2012). The urbanization externalities play an important role in concentration of business services in urban areas, but inter-sectoral linkages and intermediate demand are significant, as in many cases the spatial proximity with manufacturing clients lead KI(B)S to locate outside urban areas (Meliciani and Savona, 2015).

Theories, which suggest the concentration tendencies of KI(B)S in urban areas, consider localization and urbanization externalities as classical source of agglomeration economies first driver of the self-reinforcing process of spatial concentration of KI(B)S. Localization externalities are derived from sectoral density resulting not only in economies of scale, but also firms benefit from “monitoring advantages”, i.e. being closer to competitors to observe them, and transmit tacit knowledge via face-to-face interactions. Urbanization externalities, such as population density and capital cities are positively associated with specialization in business services, confirming that these factors facilitate knowledge spillovers (Tödtling, Lehner, et al., 2006, Meliciani and Savona, 2015). Supply-side variables, such as overall knowledge intensity of the regional workforce, i.e. high level of human capital, which is suggested to be urban-biased, is also positively influence the KI(B)S start-ups (European Commission, 2012).

The second driver of regional specialization in KI(B)S is the region specific sectoral structure which determines the intermediate demand on business services from their clients (Meliciani and Savona, 2015). Though, some authors suggest the internationalization of business services and argue that large clients prefer to utilize services by KI(B)S irrespective of location leading these services to become increasingly tradeable over distances, but still location and proximity to clients is a considerable incentive, especially when it comes to small and medium-sized firms. Forward and backward linkages expressed in frequent supplier-user interactions, is of significant importance. Local KI(B)S or local offices of KI(B)S are favored, especially by small and medium-sized enterprises (SME) as the strength of weak-ties and personal contacts with friends and business acquaintances are still crucially important in business world (Miles, 2003). As manufacturing establishments are considered to be intensive users of the knowledge intensive services, the proximity is an important incentive for KI(B)S to locate closer to their clients. Thus, the regional high and medium high-technology manufacturing sector level is considered to be a pre-condition for foundation, growth and shaping KI(B)S spatial pattern, as shown on the figure 6. Though, regions with high KI(B)S and low manufacturing specialization hint to the existence of other drivers (European Commission, 2012).

The third factor of KI(B)S localization identified from the literature is Region specific innovation and knowledge environment captured with ICT patents over population and the level of R&D expenditure over GDP (Meliciani and Savona, 2015). Results proved the significance of both variables. It is an important implication: Some authors who challenge so called "footloose hypotheses" (Wernerheim and Sharpe, 2003) argue that the development of ICT made the location irrelevant, but the distribution of ICT-related variables make difference among regions rejecting the idea that the world is flat, even in conditions of ICT development.

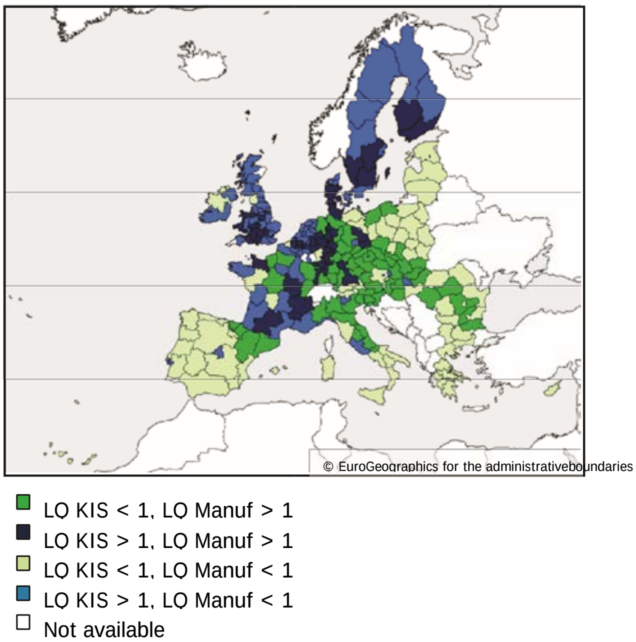

Figure 6: Location quotients of KIS and high und medium high- technology manufacturing. Source:(European Commission, 2012) based on Eurostat 2007 data. Classification according to NACE rev.1.1

The importance of ICT for KI(B)S has different explanations. Firstly, to stay competitive firms need to be Flexible, i.e. be able to meet demands of different users. Flexibility requires considerable information processing achieved through high skilled labour and intensive use of information and communication technologies. These technologies facilitate virtual interactions and enable companies access highly tacit capabilities over the world to increase their comparative advantage (Tether and Hipp, 2002, Mudambi, 2008). Moreover, knowledge intensive firms are strongly dependent on information and communication technology networks as knowledge is the key input and output of their activity transmitted through information and communication technologies (Mack, Anselin, et al., 2011). Therefore, as further explained in following part of the chapter, the ICTs, and particularly internet infrastructure, are not evenly available everywhere and thus, the impact of spatial differences of ICTs distribution pattern must be reflected in the development of KI(B)S sector in particular locations.

2.2. Internet Geography

This part of the literature review aims, at first, to describe the spatial pattern of internet infrastructure in Europe, roles and relations of and between locations in the infrastructure network and then analyse the main determinants of the spatial pattern, i.e. why some places perform better in terms of connectivity while others not. There is a widespread discussion regarding the role of internet infrastructure might play in development of regions and the next part of the literature review analysis the impact of this unequal distribution of internet infrastructure on regions and particularly, why and how it might affect the development of KI(B)S sector in regions.

2.2.1. Internet Geography

There are discussions about the definition of Internet Geography, as the internet itself includes various layers – from hard infrastructure necessary for data transmission, to the users and the content. Therefore, internet geography can be approached in different ways depending on the specific subject area. This part of the literature review focuses on the infrastructural layer of the internet in the context of urban (regional) studies (Tranos, 2009, Malecki, 2002).

Firstly, it is necessary to determine the meaning of "internet infrastructure" in the context of this literature review. Of course, the notion is quite complex, but this review focuses on the "geographic properties of the various elements of the infrastructural layer of the internet" – namely, backbone network and the broadband connections (Tranos, 2009, p.41). The backbone networks consists of long-distant high bandwidth capacity links (nowadays, mostly fiber optic ones) connecting local area networks (LANs) with each other (Malecki, 2004).

The definition of the broadband is a little bit complicated as different organizations define it in different ways. For example, the Organization for Economic Co-operation and Development (OECD) specifies a minimum speed of 256 kbps for downstream (i.e. from the network to the end point) transmissions, though broadband connections nowadays are much faster. Other organizations specify other requirements to consider a connection as "broadband". All and all, the term is used to describe internet connection which is faster than those originally used, such as dial-up service over a traditional telephone network. (Davies, 2015).

2.2.2. The backbone network from urban and regional perspective

Various authors tried to study the distribution pattern of backbone network. Why are the backbone networks so important to analyse? Connecting major hubs, these networks define the outline of the internet's physical infrastructure and show its close relationship with the urban system (Malecki, 2002). More importantly, "Global and local are mutually constitutive" – intra-urban and inter-urban networks are equally important and one can not function without the other (Rutherford, 2005a, p.2397).

Various studies showed that the internet infrastructure is unequally distributed over the world creating hub-and-spoke structure with clearly defined cores and peripheries – places with comparatively high or low connectivity, as shown on the figure 7 measures (Malecki, 2004, Rutherford, Gillespie, et al., 2004).

The studies analyzing the internet distribution pattern mainly take two measures into account: binary connections, i.e. the number of backbone connections of a city and the bandwidth capacity. In terms of reliability the number of backbone connections is crucial for a city. On the other hand, in terms of quality, the connection to a backbone is not enough for a city to have a competitive advantage. The bandwidth is the measure of quality and capacity of interconnection of a city-region to the rest of the network. Therefore, the greater the bandwidth capacity, the higher is the data transmission speed on the end user level (Tranos, 2009).

As the study of territoriality of Pan-European telecommunications backbone networks (Rutherford, Gillespie, et al., 2004) argues, there is a "three-level" core-intermediary and periphery distinction with "Golden Square" (London, Paris, Ruhr and Hamburg) as the core. Studies suggest that in addition to the traditional core areas, operators were investing in "regional capitals" – Madrid, Copenhagen, Vienna, and Prague as these cities were seen as leading urban centers for telecommunications not only in their territory, but also gateways and "regional hubs" to peripheral regions – Nordic countries and Eastern Europe. Therefore, global cities, London, New-York and Tokyo, as global hubs, remain crucially important, but other cities having geographically strategic location gain power in the telecommunications network and become increasingly important for overall network to function. (TOWNSEND, 2001, Rutherford, Gillespie, et al., 2004, Tranos, 2009).

PAN EUROPEAN FIBEROPTIC NETWORK ROUTES PLANNED OR IN PLACE

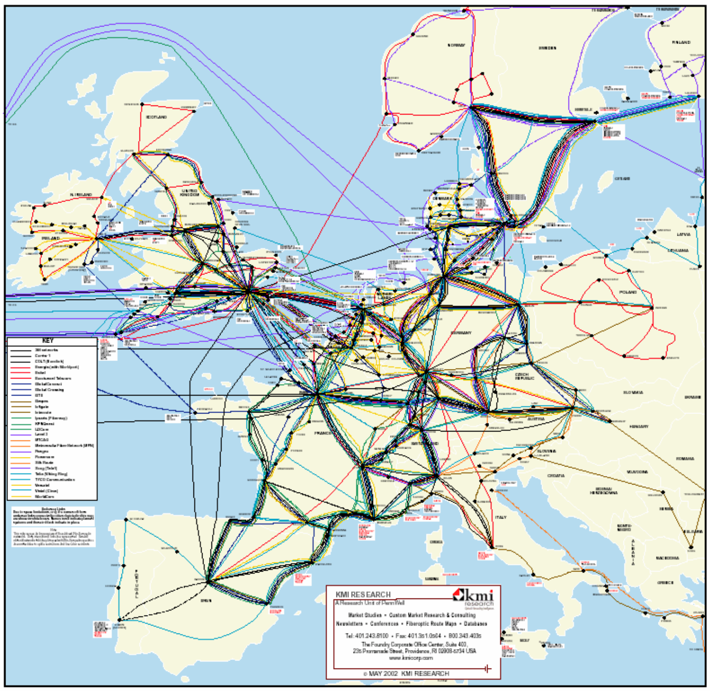

Figure 7: Fibre optic Network Routes Planned of in Place (2001) source: (Rutherford, Gillespie, et al., 2004)

More recent studies introduce different measures to analyses the performance of cities in European backbone network: binary and weighted degree, betweenness and eigenvector centrality measures (Tranos, 2011, Tranos and Gillepsei, 2011, Tranos, 2009). The betweenness centrality measure is based on binary connections and represents the likelihood of how often a city appears between any other potential origin and destination data packet route (Tranos, 2009). In other words, the betwennness centrality measure indicates how cities as nodes perform in the internet backbone network and how important a city's position is in the network or what the city's position is to control the network. (Tranos, 2009, Tranos and Gillepsei, 2011). The table #3 represents the cluster analysis based on abovementioned measures and the figure 9 is the visual representation of the cluster analysis.

To summarize, the literature identifies several roles that cities play in internet topology and that explains why some places perform better in terms of connectivity while others not. The roles are: the global hubs – cities like London, New-York, Tokyo, Paris, Amsterdam, Frankfurt; regional hubs, i.e. cities that have a convenient (gateway) position to serve as hubs not only for their hinterlands, but also the neighbouring countries – most of the cities identified in the 6th column in the table 3. In addition, other authors mention cities like Bordeaux, Montpellier as gateways to Spain and Portugal, Lyon and Strasburg towards Switzerland and Germany (TOWNSEND, 2001, Rutherford, Gillespie, et al., 2004, Tranos, 2009). Another role a city can play in internet backbone network is the hub to their hinterland. In this context, Stockholm, Copenhagen, and Hamburg were identified as main hub cities of Scandinavia and northern Germany(Tranos and Gillepsei, 2011). The last function identified from the literature is a nodal function. These cities are important nodes in their home countries but not in the overall network. The list contains cities like Dusseldorf, Hannover, Munich, Geneva, Barcelona, Dublin, Oslo, Helsinki etc. (Tranos and Gillepsei, 2011). The column with the list of these cities is not presented in the table 3. It is interesting to compare to the level of backbone connectivity and broadband coverage: as shown on figure 10, the regions creating "golden square" perform best in terms of broadband coverage, as well. It confirms that local and global are mutually dependent (Rutherford, 2005a)

Table 3: Cluster analysis based on the centrality measures for 2001 and 2006. Source: (Tranos and Gillepsei, 2011, Tranos, 2009)

	1	2	3	4	5	6
2001	London	Paris	Amsterdam, Frankfurt	Milan, Vienna	Brussels	Copenhagen, Geneva, Lisbon, Madrid, Munich, Oslo, Prague, Sofia, Stockholm, Zürich
2006	London	Paris	Amsterdam	Frankfurt	Milan, Vienna	Athens, Brussels, Budapest, Copenhagen, Düsseldorf, Geneva, Hamburg, Madrid, Prague, Stockholm, Warsaw, Zagreb, Zürich

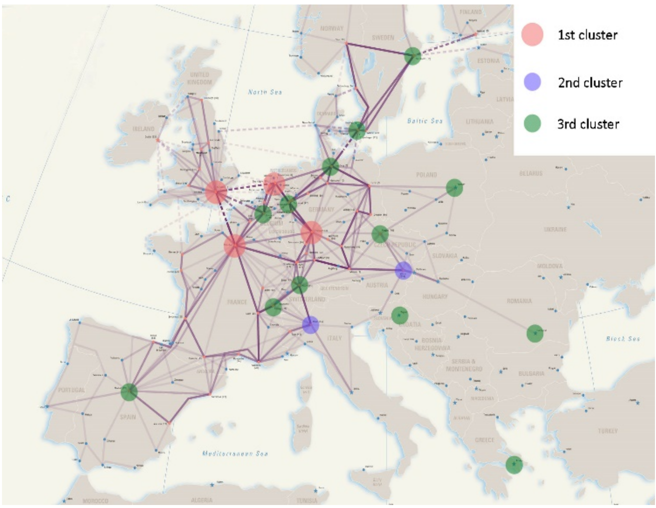

Figure 8: Visual Representation of Cluster analysis based on data provided by Telegeography, 2006. Source: Author, based on cluster analysis by Tranos (2009a)

2.2.3. Determinants of internet backbone infrastructure distribution pattern

As reviewed above, the internet infrastructure is unequally distributed. Which factors determine that shape and pattern of distribution? To answer that question, the territorial development of telecommunications should be studied from regional, market, policy, geographic, or academic perspective (Rutherford, Gillespie, et al., 2004) and briefly review the history of development of the internet which counts four main stages: in 1970-ies the Advanced Research Projects Agency Network (ARPANET) was developed by the scientists and US Department of Defence. From in 1980-ies there emerged an Internet community. From late 1980-ies to 1993 it became the US National Science Foundation Network and served as general academic resource. On the fourth stage it was transformed into general commercial infrastructure (Thomas and Wyatt, 1999).

Studies regarding the determinants of internet geography argue that there is no mono-causal explanation (Tranos, 2009). Geography matters – the internet infrastructure is quite costly to build and the cost increases with geographical distance. Therefore, geographical distance influences the probability of getting two places connected (Vinciguerra, Frenken, et al., 2010). The same study considers preferential attachment principle and argues that in addition to distance, the number of connections a place have, affects the future chances of getting even more. Taking all into account, places which are well connected or are close to well-connected places, have higher chance to improve their level of connectivity.

From geographic perspective, Tranos (2009) found the location of region on Europe's coastline positively correlated with having at least one backbone connection, while the high degree of connectedness was associated with inland regions. From geographic perspective the "gateway" position or a "phenomenon of centrally located and intermediate-size cities" (Malecki, 2002, p. 411) is a significant explanation for backbone connectivity. Some cities become regional hubs simply because of convenient position. Some locations are advantageous because they can be reached easily by other networks as well and through interconnection (IXP) a network operator is able to reach a larger number of alternative locations via other networks (in addition to one's own) (TOWNSEND, 2001, Rutherford, Gillespie, et al., 2004, Tranos, 2009, Malecki, 2002).

From market perspective, the commercialization and deregulation was one of the main drivers of development of the infrastructure (Thomas and Wyatt, 1999, Malecki, 2004). Private companies, such as Internet Service Providers, do not invest in fibre-optic lines randomly. The size of population, associated to the (potential) demand, is considered as one of the main driver of investments in backbone infrastructure and the density of population matters even more due to economies of scale. Malecki and Wei (2009) suggest that cities, like Sao Paulo, Mumbai, and Shanghai became important nodes due to their large size of population. Thus, in European context as well, the level of "metropolitan-ness" (Tranos, 2009), the level of urbanisation and population density has significant explanatory value for the level of connectedness of a region.

In addition to population size, the presence of doctoral-granting institution and economic dynamism (Malecki, 2002) or the geography of knowledge economy is positively correlated with the internet geography, but as Tranos (2009) suggests, the causality is an issue. "The geography of the knowledge economy in Europe both shapes, and to an extent is shaped by, the spatial allocation of backbone networks" (Tranos, 2009). The accessibility to business customers agglomerated in major urban centres has been the main driver for huge investments in backbone networks. Therefore, the economic dynamism and knowledge economy of a city plays a very important role (Rutherford, Gillespie, et al., 2004).

2.2.4. Broadband availability at the level of European Regions

"Broadband" means the internet access connection which provides large data transmission capacity at faster speeds than those possible connections using traditional telephone network (Davies, 2015). Thus, the broadband availability means high speed internet availability, which can be obtained at individual level via various technologies. The report series prepared for European Commission Digital Agenda analyses nine types of broadband connection, which can be obtained at individual level via various technologies: copper "twisted pair" lines, coaxial cable, or optical fibre (Valdani Vicari & Associati and IHS Inc., 2015).

While the long-distance interregional linkages (covered in the previous part) usually use optical fiber, parts of the "last mile" network, depending on the network architecture, can be using different technologies, for example, Fiber to the Cabinet (FTTC), Fibber to the Street (FTTS), Fiber to the Building (FTTB), Fiber to the Home (FTTH), Fiber to the Premises (FTTP). These technologies are using optical fiber, respectively, to the cabinet, street pole or underground, building, or home and offices, and the rest part to the end point is substituted with copper (Fiber to the Home Council Europe, 2012). The difference is that the closer the fiber comes to the end point, the higher the quality of connection is, as the fiber, compared to copper wires, has much higher capacity of transmitting signals (Davies, 2015). Though, it is rather expensive technology. The figure 9 shows network architecture principles. The differences in platforms (technologies) affect the speed of transmission and quality of connection which is crucially important companies dependent on anytime high quality internet connectivity. For example, using a copper has a distance limitation and households located outside defined distance (18 000ft) might be left without broadband access (Grubesic and Murray, 2002)

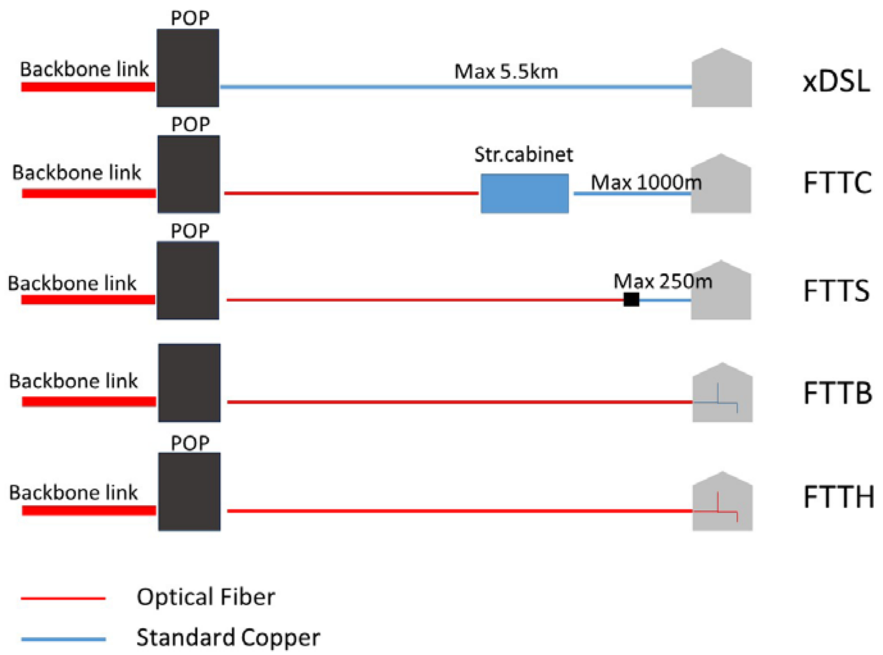

Figure 9. Network architecture. Source: Author based on (Fiber to the Home Council Europe, 2012, Valdani Vicari & Associati and IHS Inc., 2015)

The report series regarding broadband coverage in Europe (Valdani Vicari & Associati and IHS Inc., 2015) studied Overall fixed broadband (including DSL, VDSL, FTTP, Cable modem, Cable modem DOCSIS 3.0 and WiMAX) and Next Generation Access (NGA) coverage (including VDSL, FTTP and cable modem DOCSIS 3.0) coverage in European regions. The Fixed broadband technologies is more or less equally available over regions, while NGA technologies show high disparities among regions. The Figure #10 shows the regional coverage of fixed and NGA broadband in 2014.

Table 4: Network Technologies. Source: Author based on (Valdani Vicari & Associati and IHS Inc., 2015, Fiber to the Home Council Europe, 2012)

Technology	Full name	Link from POP to the end point via:
DSL	Digital subscriber line	standard (copper) telephone lines
VDSL	Very High data rate Digital Subscriber Line	standard (copper) telephone lines
Cable modem	Cable modem	coaxial cable

DOCSIS 3.0	Data Over Cable Service Interface Specification	coaxial cable
FTTP	Fiber to the Property	Optical Fiber
WiMAX	Worldwide Interoperability for Microwave Access	Non-line transmission

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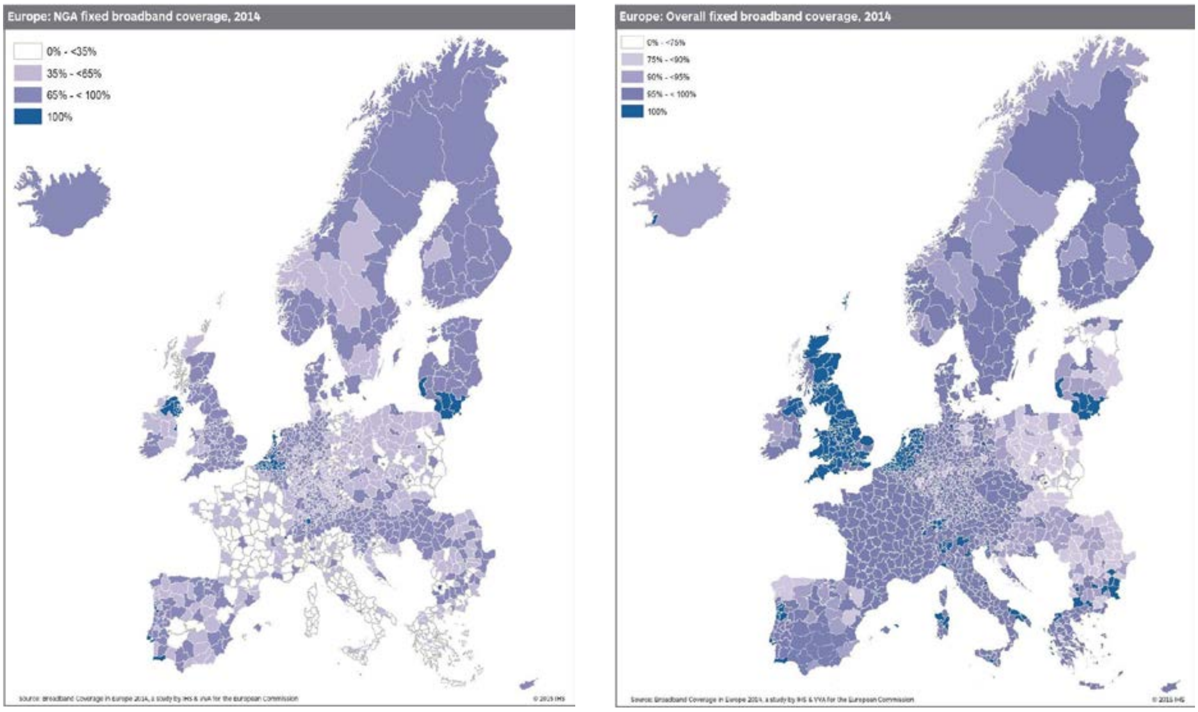


Figure 10: NGA and Overall fixed broadband coverage in Europe in 2014. Source: (Valdani Vicari & Associati and IHS Inc., 2015)

As these studies suggest, nineteen countries had fixed broadband coverage levels equals to or more then EU average, while 27 countries had fixed broadband coverage at least 90%. The measure was highest in Cyprus, Luxemburg, Malta, Netherlands, and the United Kingdom, while Poland, Slovakia, Estonia and Romania scored lowest coverage between 85.4%-89.4% of their households. The study mentions the high degree of sparsely populated and underserved rural areas to be a challenge for operators investing in broadband technologies (Valdani Vicari & Associati and IHS Inc., 2015). The highly urbanised countries, such as Switzerland, Belgium, the Netherlands, Lithuania, Luxemburg and Denmark, scored the highest in terms of NGA coverage all above 90%. France, Greece, and Italy were marked as countries with the lowest coverage of NGA technologies (Valdani Vicari & Associati and IHS Inc., 2015).

2.2.5. Impact of the Internet infrastructure on Regions

The continuously developing character of Internet infrastructure results in continuous changes in internet geography. Cities and regions which are not part of traditional core get chance to perform more important roles in European urban network due to their gateway positions in terms of global telecommunications backbone network (Tranos, 2011). Policy makers emphasize the importance of broadband coverage and policies specifically aim to improve the existing situation at regional level (Point Topic, 2012, Valdani Vicari & Associati and IHS

Inc., 2015). Therefore, it is important to capture the effect of allocation Internet's physical infrastructure on regional level (Tranos, 2012, Tranos, 2009).

Mainly, authors emphasize the importance of internet infrastructure for economic growth through increase of productivity, though the absorptive capacity of a region actually defines the extent to which internet infrastructure is able to increase the productivity (Tranos, 2012). As stated in the article, according to European Commission study a 10% increase in broadband penetration results in increased GDP by 1 to 1.5% (Davies, 2015). Some authors argue that the unequal allocation of internet infrastructure has impact on innovation capability of regions resulting in enhanced innovation performance (Vinciguerra, Frenken, et al., 2011).

The concentration of internet infrastructure in a specific location may have positive impact on economic activities due to various reasons. Tranos et.al (2013) use a concept "digital accessibility" (DA) defined as the "potential for virtual interactions which have the form of digital communications" (Tranos, Reggiani, et al., 2013p.2). The author argues that concentration of internet infrastructure in a specific location can provide better access to the backbone of the digital economy. It will affect the competitiveness at different levels not only through increase of efficiency, effectiveness, but also cost reduction and revenue increase for large corporations. All and all it positively influences on the attractiveness of these places through connectivity and accessibility as location endowment factor (Tranos, Reggiani, et al., 2013). As it is explained, in reality, geographic location has an impact on internet connectivity and speed of data transmission due to the uneven spatial allocation of the physical infrastructure – routers, switches, fibre optic links, etc. (Tranos and Gertner, 2012). As a result, Tranos et.al. (2013) argue that concentration of internet infrastructure will increase the attractiveness of this place for firms that are crucially dependent on such kind of infrastructure – financial sector, creative industries, knowledge intensive firms, and etc. (Tranos, 2009). Therefore, the following part of the literature review tries to find connection between internet geography and knowledge intensive business services, as these firms are most likely to be dependent on any time high quality internet connectivity.

2.3. The impact of internet on Knowledge Intensive (Business) Services

2.3.1. Internet geography and firms locations

The theories regarding the impact of internet on firm location can be grouped into three main directions. The first direction predicted that ICTs might be only a complementary tool for face-to-face interactions which actually would reinforce the central city location advantages and lead to even more concentration of commerce activities in urban areas. (Gaspar and Glaeser, 1998). The urban-biased pattern of internet infrastructure somehow supports this point of view.

The second direction implied that ICT would be a force leading to deconcentration by enabling firms to have real time interactions and locate away from expensive central city districts (Steinfield, 2004). The third direction argued that the effect of internet would not be strictly homogenous and the firms would be able to have a choice between benefits of central city or peripheral locations, dependent on characteristics and strategies of the firms. Other factors, such as industrial composition of regional economies would have also an impact on the strength of relation between ICT and firms location (Mack, 2014). The problem with the theories is that the first one assumes the clustering of this infrastructure in central places, while the second assumes homogeneous distribution of internet infrastructure (Mack, Anselin, et al., 2011) In fact, as described above, the distribution of internet infrastructure is far from being ubiquitous and nowadays other than central places also benefit from them. Thus, the impact it generates, is more complicated to predict (Tranos and Gillepsei, 2009b, Malecki, 2004, Malecki, 2002, Rutherford, 2005b).

2.3.2. Internet geography and knowledge intensive business services

The previous part of the literature review discussed theories regarding the impact of internet on firms' location. The knowledge intensive business services are one of the most intensive users and crucially dependent on any-time high quality broadband connection. Thus, the impact of broadband on KI(B)S establishments is worth to study in spatial context. Mack (2014) examined the relationship between broadband provision and knowledge intensive firm clusters using bivariate Moran and the bivariate local Moran to explore the correspondence between the levels of broadband provision and KI(B)S locations at the level of the US countries. The study finds statistically significant correlation between levels of broadband provision and knowledge intensive establishments, though the results are biased with large metropolitan areas. The local Moran, which allows to see the countries where the spatial relationship of variables is statistically significant, showed four different cases of relationship: high level broadband countries surrounded with large number of KI establishments (high-high); low broadband levels with small number of KI establishments (low-low), low broadband with large number of KI establishments (low-high) and high level of broadband level countries with small number of KI establishments (high-low) (Mack, 2014).

The variety of results confirm that there is not a homogeneous impact of broadband on knowledge intensive firms' locations. While high-high countries confirm the importance of broadband in knowledge intensive sector, the existence of high-low and low-high countries suggest that alternative location factors are important for attracting knowledge intensive establishments. The high-low countries reinforce the theory of centralization impact of ICT over firms' locations: the countries with high broadband levels, and thus, higher digital accessibility, still are unable to overcome the forces of centralization and agglomeration economies in larger metropolitan areas (Mack, 2014). On the other hand, the low-high countries exhibit an interesting pattern of distribution: half of them are not major metropolitan areas and are located between metropolitan areas. The author concludes that the broadband enables knowledge intensive firms strategically locate close to metropolitan areas and benefit from proximity without high costs.

Tranos and Mack (2015) tried to find causal relationship between broadband provision and knowledge intensive firms' location across United States using granger causality test with panel data framework. The figure 10 illustrates the study results, which are grouped into two categories: broadband provision causes KIBS growth, vice versa, two-directional causality and no significant causal relationship. The study tries to find the socio-economic and geographic factors that affect the probability for each abovementioned causal direction using multinomial logit model. The results suggest positive impact of internet infrastructure's early adoption (captured by the level of broadband in 1999) on likelihood of causality running from broadband to KIBS. The population density, human capital, and the agricultural activities were positively related to the probability that a country is able to leverage an increase broadband provision to growth of the KIBS. Though, the population size had negative impact.

The literature discussed above suggests the importance of broadband provision for KIBS. The researches in the United States proved that the relationship between these two variables is context dependent and varies over countries.

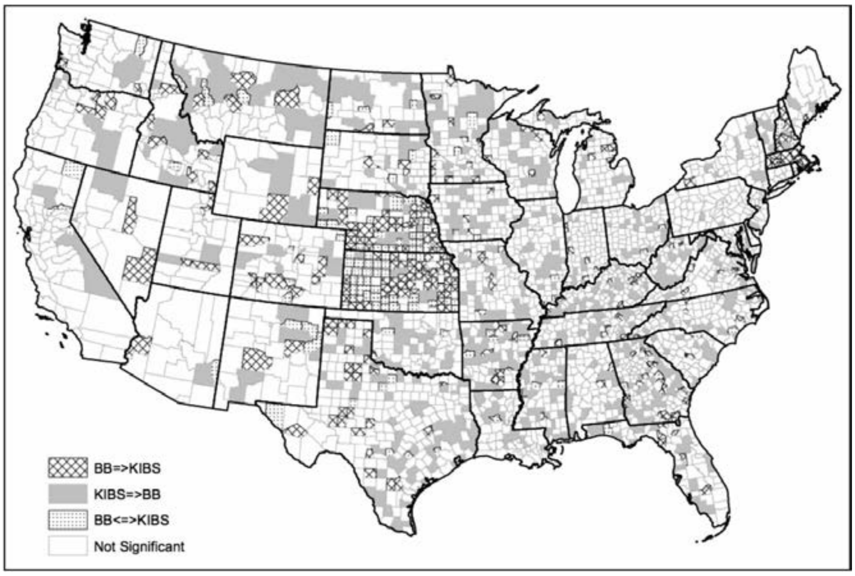


Figure 11: Results of Granger causality test. Causality between broadband provision and KIBS. Source:(Tranos and Mack, 2015)

2.4 Conceptual Framework

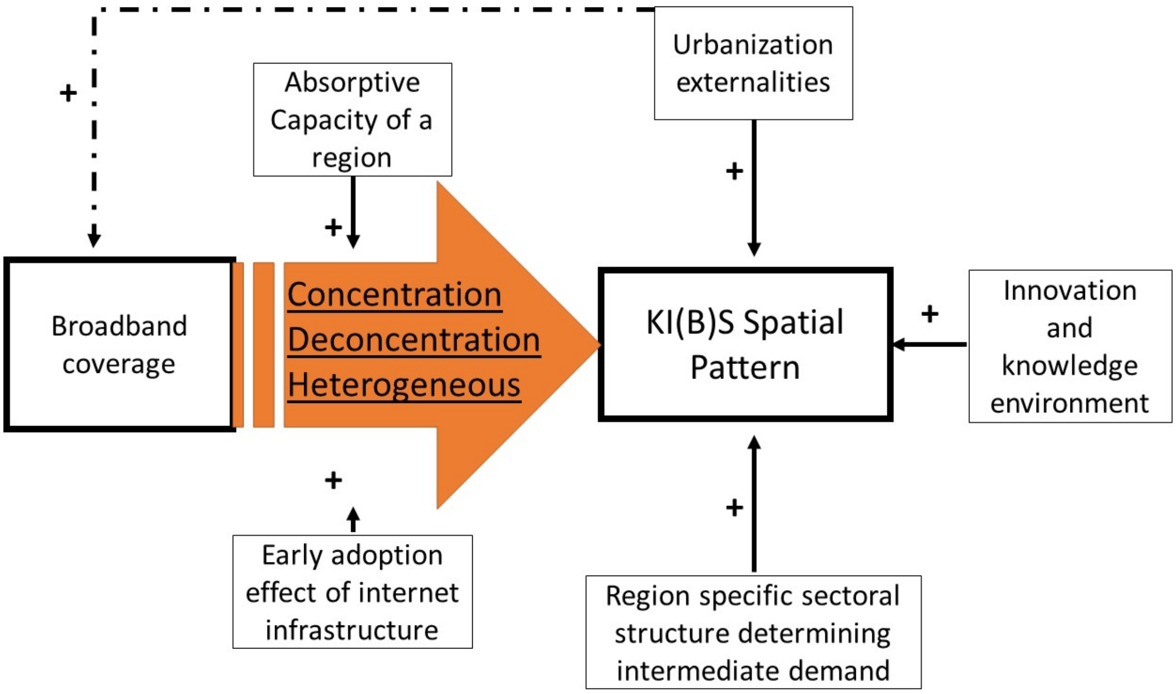


Figure 12: Conceptual Framework, Source: Author, 2016

The conceptual framework identifies dependent and independent variables. The dependent variable is the spatial pattern of KI(B)S across European regions and the independent variable is the broadband provision. As derived from the literature, the KI(B)S spatial pattern is influenced by groups of other factors, such as localization and urbanization externalities, region specific sectoral structure determining intermediate demand, and region specific innovation and knowledge environment (Meliciani and Savona, 2015). Thus, the study aims to find the significance of broadband provision in comparison with other factors.The literature regarding the impact of ICTs on firms location suggests three possible outcomes: Centralization, decentralization and heterogeneous. The conceptual framework identifies those possible relationships as well.

The studies across united states confirmed that the broadband provision is an important factor influencing the KI(B)S firms location (Tranos and Mack, 2015, Mack, 2014), though the relationship between these variables is influenced by other factors, such as early adoption of internet infrastructure by a region and absorptive capacity of a region (Tranos, 2012, Tranos and Mack, 2015). The conceptual framework defines not only dependent, independent, and control variables, but factors that affect the relationship between them.

Chapter 3: Research Design and Methods

3.1.1 Revised Research Question(s)

Main research question:

What is the comparative importance of broadband coverage to the level of KI(B)S sector development across European regions?

There are three sub-questions of the research:

To what extent the level of broadband provision is related to the spatial pattern of KI(B)S while controlling for the other groups of factors for years 2011-2013?

Is the regional specialization in KI(B)S sector spatially related to the level of broadband provision in European regions for 2014?

Does the comparative importance of broadband coverage for development of KI(B)S sector vary across sub-regions of Europe for 2014?

3.1.2 Operationalization: Variables, Indicators

Spatial pattern of KI(B)S – this paper defines knowledge intensive (business) services as those "whose activities have a high knowledge component" (European Commission, 2012, p.6). The main characteristic of these firms – high knowledge intensity – is mainly measured by levels of staff with high professional qualifications and degrees. Knowledge intensive (business) services are following according to NACE rev. 2: information and communication (J); Financial and insurance activities, real estate activities (K_L); professional, scientific and technical activities (M); administrative and support service activities (N); public administration, defence, education, human health and social work activities (O_Q)

The innovation research during last decades showed that the innovative activities of business firms are influenced by regional factors and endowments resulting in formation of region-specific innovation modes and spatial differences over regions in terms of KI(B)S sector development. The study of European Commission Knowledge Intensive (Business) Services in Europe (European Commission, 2012) uses localization quotient, the employment share of KI(B)S and KI(B)S growth rate as indicators of regional sector development. As the focus of this research is the spatial pattern of KI(B)S across regions in Europe, the main indicator chosen for analysis are the share of KI(B)S in total employment over regions, but for comparison the analysis using localization quotient as dependent variable is included in the appendix as well.

As derived from the literature the regional specialization in KI(B)S is influenced by groups of factors, such as urbanization externalities as source of agglomeration economies, region specific sectoral structure determining intermediate demand, and region specific knowledge and innovation infrastructure (Meliciani and Savona, 2015).

Urbanization externalities – The literature has underlined the crucial role of urbanization externalities for business services arguing that the proximity to the clients and to the skilled labor is believed to be an important incentive for KI(B)S (Meliciani and Savona, 2015, Glaeser, 1999). Measures frequently used in literature to capture urbanization externalities are population density and regions with capital cities (Meliciani and Savona, 2015).

Region specific sectoral structure determining intermediate demand – the importance of forward and backward linkages for development of KI(B)S sector is highlighted in literature. Thus, region specific sectoral structure, i.e. proximity to main customers is argued to be main driver of regional specialization in knowledge intensive business services. The proximity to manufacturing clients is important incentive for KI(B)S. The regional manufacturing, high and medium high-technology manufacturing structure is considered to be one of the pre-conditions for foundation, growth and shaping KI(B)S spatial pattern (European Commission, 2012, Miles, 2003, Miles, Kastrinos, et al., 1995b, Meliciani and Savona, 2015).

Region specific innovation and knowledge environment – Despite the argument that the ICT development has changed the way knowledge goods and services are produced, transmitted and traded, leading to fading away the importance of location (Friedman, 2005), some authors argue the location of KI(B)S is not independent from the local innovation and knowledge environment. As highlighted in the article, alongside ICTs, complementary assets, such as availability of human capital, and public R&D expenditure influence the regional specialization in KI(B)S (European Commission, 2012, Meliciani and Savona, 2015).

Broadband coverage - "Broadband" means the internet access connection which provides large data transmission capacity at faster speeds than those possible connections using traditional telephone network (Davies, 2015). According to Mack (2014) broadband provision vary in terms of availability, speed, platforms (i.e. technologies or combinations of technologies which result in differences in speed) and market competition. While studies in the US use number of providers as proxy for the level of competition instead of indicators of actual platforms and speed variations. In the context of European regions using number of providers as an independent variable might cause a problem, as telecommunications is considered as part of knowledge intensive services which is used as dependent variable. Therefore, instead of number of providers, this paper uses availability and platforms (combination of technologies).

For platforms (technology combinations) two indicators are used: Next Generation Access (NGA) coverage (which is combination of VDSL, FTTP and cable modem DOCSIS 3.0 technologies) and overall fixed broadband coverage ((including DSL, VDSL, FTTP, Cable modem, Cable modem DOCSIS 3.0 and WiMAX technologies). The variables, instead of actual take-up of these services, measure the coverage, i.e. the percentage of households, who are able to subscribe the services if they are willing to do so. The data was collected for EU and associated countries (Norway, Iceland, and Switzerland) on NUTS 3 regional level, which means smaller regional units of 15 000 to 800 000 inhabitants. The data was obtained through a survey of Internet Service Providers (ISPs) and National Regulatory Authorities (NRAs); and a review of alternative sources, such as operator web-sites, white papers, and reports.

For this research two publicly available indicators are used: The NGA and overall fixed broadband coverage. The data for years 2011-2013 is extracted from maps of annual reports at NUTS 3 level at ordinal scale and can not be aggregated at NUTS 2 level. The data for 2014 is available at NUTS 3 level, but it also can be aggregated at NUTS 2 level. Thus, separate dataset is built for research sub-question 1 and the rest of research questions.

Table 5: operationalization

concept	variable	indicator	years	database	measure
Spatial pattern of KI(B)S	Regional KI(B)S sector development	Employment share in KI(B)S	2011-2013, 2014	EUROSTAT	percentage
		Location quotient	2011-2013, 2014	Eurostat	continuous
Broadband provision	platforms	Percentage of households having access to overall fixed broadband technologies	2011-2013, 2014	Report series Broadband Coverage in Europe prepared for European Commission Digital Agenda	percentage
		Percentage of households having access to NGA technologies	2011-2013, 2014	Report series Broadband Coverage in Europe prepared for European Commission Digital Agenda	percentage
Urbanization externalities	Proximity	Population density	2011-2013, 2014	EUROSTAT	continuous
		Regions with capital cities	2011-2013, 2014	EUROSTAT	dummy
		Urban-rural typology of regions	2011-2013	EUROSTAT	categorical
Region specific sectoral structure determining intermediate demand	Proximity to main – manufacturing - customers	Employment share in manufacturing	2011-2013, 2014	EUROSTAT	continuous
		Employment share in high and medium high technology manufacturing			

Region specific innovation and knowledge environment	Human capital	Share of population aged 25-64 with tertiary education	2011-2013, 2014	EUROSTAT	Percentage
		Share of Population aged 15-64			
	R&D expenditure as percentage of GDP	Total intramural R&D expenditure over regional GDP	2013	EUROSTAT	Percentage

3.1.3 Research strategy

The nature and scale of the research questions leads to choose the secondary quantitative data analysis as a main research strategy. The analysis is based on secondary databases, which is further described below.

3.1.4 Data Collection Methods

The data from dependent variable is collected from EUROSTAT database and indicates the employment share in KI(B)S.

The data for main independent variable broadband provision – is collected from annual reports of European Commission's Digital Agenda. The report series are available from 2011 to 2015, but the data will be extracted only till 2013, as the dependent variable data with less amount of missing values at NUTS 3 regional level is available only till 2013.

The report series make distinction between Standard fixed broadband and NGA broadband coverage, as the later includes the technologies which are needed to meet the Digital Agenda 30Mbps objective and is less spread compared to the standard fixed broadband. The data will be collected from the maps provided in the reports, indicating the percentage of households having access to that technology, i.e. being able to "subscribe to the service without requiring significant additional investment to connect the household to the technology network" (Valdani Vicari & Associati and IHS Inc., 2015). The data is available at the level of NUTS 3 regions and it is at ordinal scale.

The data for control variables are collected from Eurostat database. Urbanization externalities are captured by population density, "regions with capital city" and "urban-rural classification of regions" dummy variables. The population density is continuous and indicates population per square kilometre (including water and land surface). The regions with capital city dummy variable marks a region with 1 if it is a region with a capital city and 0 – otherwise. The urban-rural classification of regions are obtained from EUROSTAT database. The data was collected at NUTS 3 regions level based on OECD methodology, which classifies regions as predominantly urban, intermediate or predominantly rural regions. The classification is based on the percentage of population living in rural areas, though the presence of a city with inhabitants more than 200 000 changes the status of rural region into intermediate, and a city with 500 000 inhabitants – into predominantly urban despite of the share of rural population. In the data obtained from the Eurostat database 1 stands for predominantly urban, 2 – intermediate, and 3 – predominantly rural regions.

The region specific sectoral structure determining intermediate demand is captured by the employment share in manufacturing and high and medium high technology manufacturing – as main customers of KI(B)S. The data is available as thousand persons and the percentage of the sector in total employment is calculated afterwards. To define the high and medium high technology manufacturing sectoral approach was used, which means to aggregate manufacturing industries according to technological intensity, which is captured with R&D expenditure/value added. The economic sectors classification into high-technology, medium high-technology, medium low-technology and low-technology industries is based on the R&D intensity. For this research an aggregate indicator is used – employment in high and medium-high technology manufacturing.

The *Region specific innovation and knowledge environment* is measured by the level of human capital (active population (aged 25-64) with tertiary education and population aged 15-64) and total R&D expenditure as percentage of GDP in previous year (2013). The indicators for human capital are available at NUTS 3 or NUTS 2 level, while the data for total R&D expenditure is available only for NUTS 2 level. All variables are available at Eurostat database.

3.1.5 Data Analysis Methods

The data analysis methods differ by research sub-objectives. For the first sub-objective panel data analysis method is used – fixed or random effects (fixed effects, as indicated by hausman test) to capture the impact of broadband provision on KI(B)S over years. The research afterwards uses spatial analysis techniques. For the second research sub-objective univariate and bivariate Global and Local Moran's I are employed to understand the spatial pattern of both, dependent and independent variables and explore spatial relationships between them. The exploratory analysis technique is quite useful tool but it does not allow one to actually conclude the impact of one variable on another in the context of other factors. Therefore, it is needed to capture the significance of the main independent variable in comparison with other groups of factors in spatial context. For this purpose, maximum likelihood spatial lag/error model is employed first including all the regions of the study area and afterwards – Western, Eastern, Northern and Southern Europe separately to understand weather the relationship between variables are homogenous or differ across sub-regions.

3.1.6 Validity and reliability

The validity and reliability are important criteria for scientific research. The reliability is necessary but not sufficient for reliability and means the accuracy and consistency of measured variables (Thiel, 2014). The reliability for this research is based on the authoritative databases, such as Eurostat. The data of broadband coverage is collected from annual reports prepared by consultancy companies for European Commission. Thus, the reliability is derived from reliable databases.

The internal validity measures whether the theoretical constructs was adequately operationalized and whether the causal relationship between variables actually exist (Thiel, 2014). The theoretical concepts, such as KIBS and internet infrastructure spatial patterns were adequately operationalized – the indicators actually measure what is intended to measure. The second part of the internal validity – existence of causal relationship between variables – can be proved by previously mentioned studies in the United States by Elizabeth Mack and Emmanouil Tranos (Mack, 2014, Tranos and Mack, 2015, Mack, Anselin, et al., 2011). Though, there are other studies, which consider KIBS with other variables as predictors for internet infrastructure pattern development. The external validity describes the extent to which a study can be generalized. The research does not imply generalization and it only studies what it intends to study.

Chapter 4: Research Findings

4.1. Data preparation process and description

4.1.1. Data Collection

The data was collected from secondary sources, such as EUROSTAT, online database and annual reports regarding broadband coverage in Europe prepared for European Commission's Digital Agenda scoreboard by Point Topic, HIS Inc. and Valdani Vicari & Associati. The data from these sources are available by NUTS (Nomenclature of Territorial units for statistics) classification of regions. The data was collected either at NUTS 2 or NUTS 3 level. NUTS 2 is basic regional division for application of regional policies, while NUTS 3 is classification of smaller regions for specific diagnoses. The NUTS 2 regional classification contains 276 and NUTS 3 – 1342 regions.

The analysis at NUTS 3 level includes regions of EU, and Norway. The annual reports maps of broadband coverage in Europe were based on NUTS 2010 classification, while the data for dependent variable used NUTS 2013 classification. Thus, the regions, which were different due to changing borders or division of regions were excluded from analysis. These are mostly regions in Poland, Portugal and a few German regions. The total number of observations of three years panel data was 4104.

The analysis at NUTS 2 level includes 259 regions in total of countries shown on the table 6. Due to unavailability of main independent variable data, Norway, Switzerland, part of Croatia, Luxemburg and three German regions are not included in analysis.

Table 6: List of Countries included in Analysis at NUTS 2 level.

Country	Code	Country	Code	Country	code
Austria	AT	France	FR	Netherlands	NL
Belgium	BE	Croatia	HR	Poland	PL
Bulgaria	BG	Hungary	HU	Portugal	PT
Czech Republic	CZ	Ireland	IE	Romania	RO
Germany	DE	Italy	IT	Sweden	SE
Denmark	DK	Latvia	LV	Slovenia	SI
Estonia	EE	Lithuania	LT	Slovakia	SK
Spain	ES			United Kingdom	UK
Finland	FI				

4.2. Empirical Results

4.2.1. RQ1: To what extent the level of broadband provision is related to the spatial pattern of KI(B)S while controlling for the other groups of factors for years 2011-2013?

4.2.1.1. Dependent variable

The data for dependent variable was collected from EUROSTAT database. For analysis at NUTS 3 level Employment in information and communication, Financial and insurance activities; professional, scientific and technical activities; administrative and support service activities; public administration, defense, education, human health and social work activities (based on NACE rev.2 from reference year 2008) measured in thousand persons were summarized as knowledge intensive business services and the share of it in total employment was calculated, as well as location quotient, which was used for robustness check included in appendix.

The location quotient enables one to determine the region specialization in knowledge intensive business services. Regions with LQ greater than one are considered as specialized in the sector, while the score under one indicates that a region is not specialized in this sector. The LQ is calculated as follows:

$LQ=(e_i/e)/(E_i/E)$

Where

- e_i is employment in knowledge intensive business services in regional economy

- e is the total employment in the region

- E_i is the employment in KI(B)S in national economy

- E is the total employment in the national economy

Table 7 shows summary of dependent variables data for years 2011-2013. Table 8, 9, 10 show summary of dependent variable for each year. As we see on the tables, the mean from 2011 to 2012 increased slightly and for 2013 decreased again. The minimum and maximum values are more or less stable over years. The highest level of regional specialization is observed in Region of Brussels (BE100), while the lowest level of specialization for all years is for one and the same border region of Germany (DE249).

Table 7: summary table of dependent variables for years 2011-2013

Variable	obs	Mean	Std.Dev.	Min	Max
Employment share in KI(B)S	4,096	27.62479	12.87194	6.500751	67.81509
Location Quotient of KI(B)S	4,096	0.8917514	0 .2432659	0.1720259	2.187784

Table 8: Summary table of dependent variable for year 2011

Variable	obs	Mean	Std.Dev.	Min	Max
Employment share in KI(B)S	1368	27.89421	12.75887	6.500751	67.01016
Location Quotient of KI(B)S	1,368	0.9037616	0.2349636	0.1720259	2.124192

Table 9: Summary table of dependent variable for year 2012

Variable	obs	Mean	Std.Dev.	Min	Max
Employment share in KI(B)S	1,364	28.06085	12.85229	6.799407	67.36827
Location Quotient of KI(B)S	1,364	0.9029314	0.2339558	.1805223	2.187784

Table 10: Summary table of dependent variable for year 2013

Variable	obs	Mean	Std.Dev.	Min	Max
Employment share in KI(B)S	1,364	26.91853	12.98382	6.882677	67.81509
Location Quotient of KI(B)S	1,364	0.868526	0. .2586127	0.1771383	2.104269

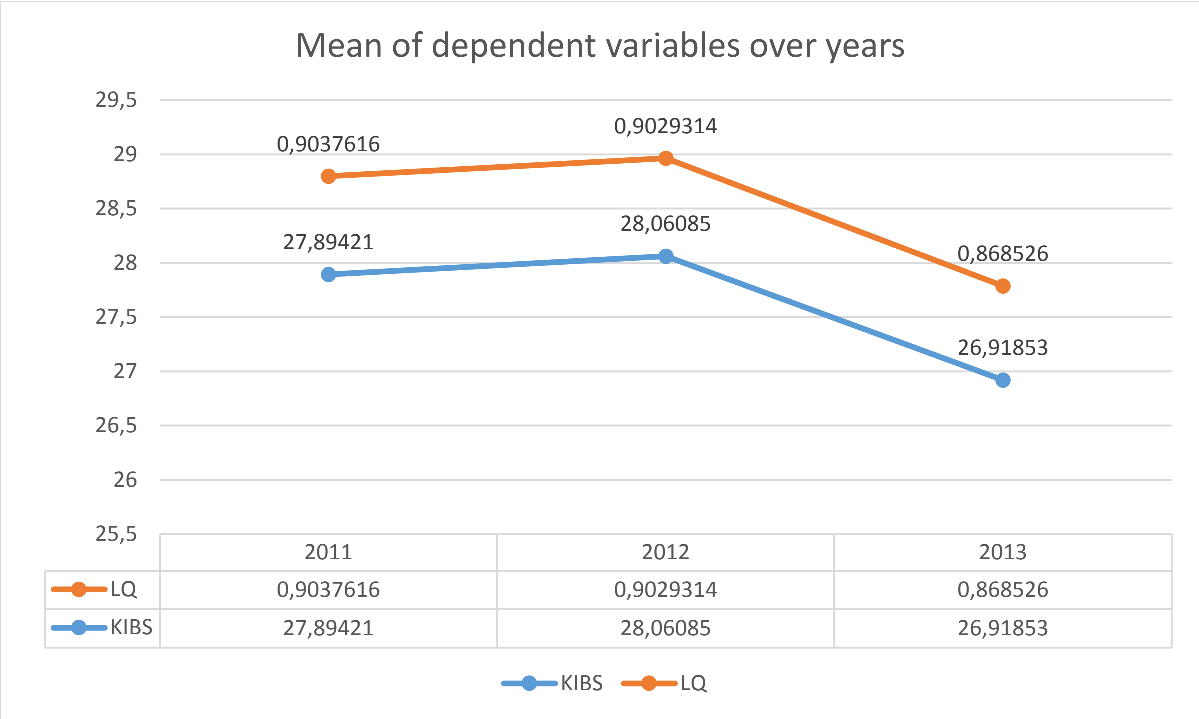


Figure 13: Trends of mean of dependent variables for 2011-2013 years

4.2.1.2. Independent variables

The data at NUTS 3 level for the 1st research sub-question for years 2011-2013 was obtained from maps included in annual reports regarding broadband coverage prepared for European Commission's Digital Agenda scoreboard. Following variables were obtained from these reports: overall fixed broadband coverage and Next Generation Access broadband coverage. The overall fixed broadband coverage includes following technologies: DSL, VDSL, FTTP, Cable modem, Cable modem DOCSIS 3.0 and WiMAX. The Next Generation Access broadband coverage is the combination of following technologies: VDSL, FTTP, and cable modem DOCSIS 3.0. These technologies are capable to reach speed at least 30mbps and are of particular interest. Instead of actual take-up, the variables indicated the percentage of homes within the area (NUTS 3 region) which have access to that technology. Having access means "being able to subscribe to the service without requiring significant additional investment to connect the home to the technology network" (Point Topic, 2012, p.164). The data extracted from the map was of ordinal scale, where for overall fixed broadband coverage numeric values were attached as following:

1) 0 - <75% coverage 2) 75-<90% coverage 3) 90-<95% coverage 4) 95-<100% coverage 5) 100% coverage

The NGA coverage data included values as following:

1) 0-<35% coverage; 2) 35-<65% coverage; 3) 65-<100% coverage; 4) 100% coverage;

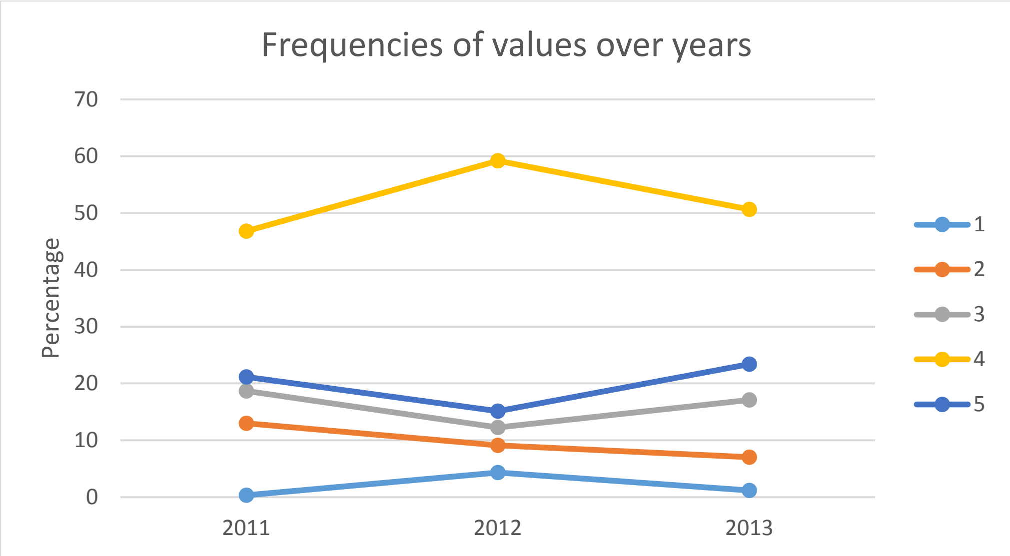


Figure 14: Frequencies of Standard Fixed Broadband Coverage values over years

As shown on the figure 14, the highest number of regions over years were with standard fixed broadband covering 95-<100% of population, suggesting that presence of broadband technologies is no longer an issue over European Regions. While for NGA coverage, as shown on figure 15, the highest number of regions in 2011 were with 0-35% NGA broadband coverage, but the trend changed over years – number of regions with low NGA coverage decreased, while number of regions with high (65-100%) coverage significantly increased from 2011 to 2013 suggesting that more attention is payed to the NGA technologies.

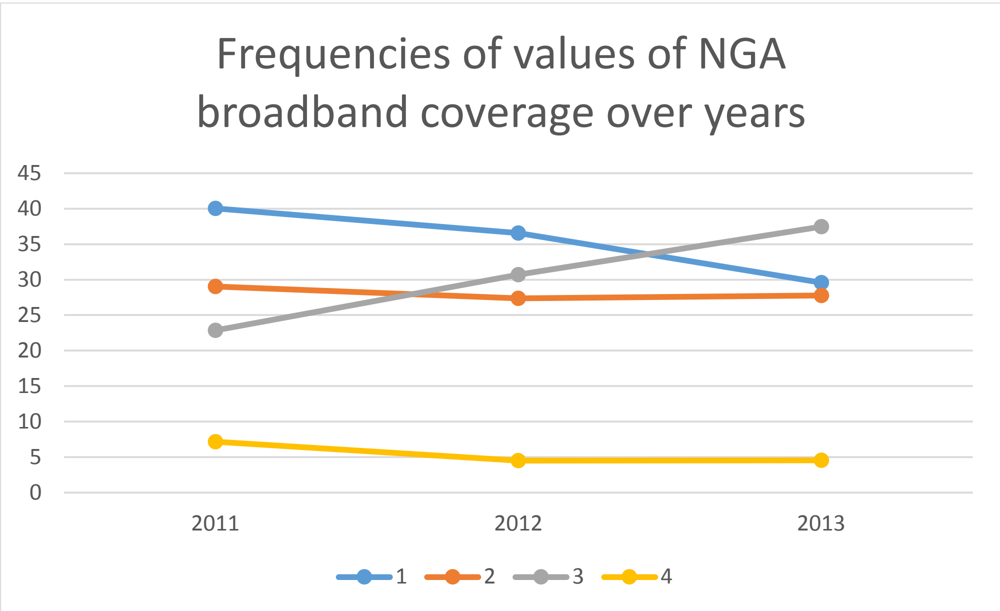


Figure 15: Frequencies of NGA broadband coverage values over years

4.2.1.3. Control variables

In addition for main independent variables three groups of control variables were included in the analysis in order to account for other factors which might affect the spatial pattern of Knowledge intensive business services.

The first group of variables are associated to urbanization externalities and are as follows: population density, regions with capital cities, and urban-rural classification of regions according to EUROSTAT. The second group of control variables are included to account for the intermediate demand on those services from their customers. As derived from the literature, manufacturing sector establishments are considered to be the clients of KI(B)S. Thus, the employment share in manufacturing was included to account for region specific sectoral structure determining intermediate demand on business services. The next group of control variables are related to the regional innovation environment captured by level of human capital - the percentage of population aged 15-64. The table 11 shows summary statistics for control variables.

Table 11: Summary statistics table for control variables

Variable	Obs	Mean	Std.Dev.	Min	Max
Population Density	3,754	463.4188	1055.064	1.6	21302.6
Regions with capital Cities	4,080	-	-	0	1
Urban-Rural Classification	3,660	-	-	1	3
Employment share in manufacturing	3,804	16.22987	8.268067	1.08218	49.15106
Percentage of population aged 15-64	3,660	65.89224	2.56349	58.43918	75.44301

4.2.1.3. Summary

To summarize the description of variables included in the analysis, correlation matrix was created, shown on the table 12. The highest positive correlation of dependent variables are observed with regions with capital cities and standard fixed broadband coverage. The subject of main interest, standard fixed and NGA broadband coverage are positively correlated with both, location quotient and employment share of KI(B)S. The highest correlation of standard fixed broadband coverage is with population density, suggesting the importance of economies of scale for internet service providers, while the NGA coverage is highly correlated with regions with capital cities. It means that the primarily capital cities benefit from new technologies.

From control variables we see that urban-rural classification is negatively related to percentage of population aged 15-64, population density and regions with capital cities, meaning that predominantly rural (3) regions are the ones with lower level of human capital then predominantly urban regions (1). Population density is negatively correlated to the manufacturing share in total employment, suggesting the tendency of locating manufacturing establishments outside densely populated urban areas and that might balance the centripetal force in terms of attracting business services (Meliciani and Savona, 2015). The highest positive correlation is between the percentage of population aged 15-64 and regions with capital cities suggesting the attracting force of capital cities in terms of human capital.

Table 12: Polychoric correlation matrices of variables. Source: Author, 2016

Variables	Location quotient	Empl.share in KI(B)S	Urban-rural classification	Standard fixed broadband coverage	Population density	Next Generation Access broadband coverage	manufacturing share in total employment	regions with capital cities	percentage of population aged 15-64
Location quotient	1								
Empl.share in KI(B)S	0.5886284	1							
Urban-rural classification	-0.45197816	-0.22136254	1						
Standard fixed broadband coverage	0.34484172	0.34867788	-0.55309268	1					
Population density	0.45890007	0.15306421	-0.74736501	0.54436736	1				
Next Generation Access broadband coverage	0.23815787	0.2651183	-0.48848522	0.50858076	0.454813	1			
manufacturing share in total employment	-0.40726886	-0.456626	0.18623073	-0.324282	-0.22467	-0.1332473	1		
regions with capital cities	0.52619529	0.57500111	-0.98482986	0.32067831	0.458922	0.31729095	-0.592751	1	
percentage of population aged 15-64	0.08155956	-0.04251333	-0.11023374	-0.19975889	0.20138	0.10046447	0.0950588	0.468684	1

4.2.1.4. Data analysis method

After checking for outliers the test for normality was performed. New data point “residuals” were created and Jarque –Bera test was used. The p value (5.e-177) indicated that null hypotheses can not be rejected, thus the data is normal. To test the data for homoscedasticity Breusch-Pagan test was used. The significant P value (0.0000) rejected the null hypotheses, concluding that there is heteroscedasticity in data. Thus, as a correction “robust” command was used in final regression. The VIF proved that the multicollinearity is not an issue for the dataset. To test weather model specification is correct or not, at the first stage link test was performed. The insignificant p value (0.061) of created new variable _hatsq failed to reject the null hypotheses which states that the model is specified correctly. For the second stage regression specification error test (RESET) for omitted variables was performed. The significant p value (0.0000) indicates that there is a model specification error and some important variables are omitted. As the impact of broadband on KI(B)S is the main issue of interest and the control variables are derived from the literature, the model is not reconsidered. To find the appropriate model of panel data linear regression hausman test was performed to find out which model – fixed effects or random effects model is the most appropriate one.

The fixed effects model figures the relationship between independent and dependent variables within an entity, in our case – NUTS3 regions, taking into account characteristics of individual regions, which might or might not affect the dependent variable – regional specialization in KI(B)S, thus we need to control for that. FE model removes the effect of individual time-invariant characteristics and allows to capture the net effect of the independent variables on dependent variables. The equation for the fixed effects model is:

$Yit = \beta 1Xit + \alpha i + uit$

Where:

- αi (i=1….n) is the unknown intercept for each entity (n entity-specific intercepts).
- Yit is the dependent variable (DV) where i = entity and t = time.
- Xit represents one independent variable (IV),
- $\beta 1$ is the coefficient for that IV,
- uit is the error term

The difference between fixed and random effects model is that the later assumes the variation across entities to be random and uncorrelated with the predictor variables in the model. Unlike the fixed effects model, one can include time-invariant variables in the model. The random effects model is:

$Yit = \beta Xit + \alpha + uit + \varepsilon it$

Where:

-εit stands for within-region error

- uit stands for the between-region error (Torres-Reyna, 2007)

The hausman test significant chi2 value rejected the null hypotheses, which states that the random effects model is appropriate. Thus, the fixed effects model was chosen. As mentioned above, the outliers and influential points were checked. In the analysis presented in the research the outliers and influential points were excluded. Though, the results of analysis including “outliers” and influential points” are included in appendix for robustness check. It is necessary to mention that having only three years of panel data in Fixed Effects model might give spurious results.

4.2.1.5. Data analysis results

To determine whether the broadband coverage has an impact on KI(B)S sector development, the model was constructed without control variables at first. The model includes both, standard fixed and NGA broadband coverage, but only NGA coverage exhibits statistically significant positive effect (coefficient 0.166) on knowledge intensive business services, meaning that the improvement of broadband coverage from 0-35% to 35-65% coverage is related to the increase of KI(B)S employment share by 0.166%. The insignificance of standard fixed broadband coverage and significance of NGA coverage confirms that the presence/absence of broadband is not an issue nowadays, what makes difference is the combinations of technologies determining the speed and quality of the connection. The model explains only 0.2% of dependent variable.

Table 13: explaining the employment share of Knowledge intensive business services

VARIABLES	(1) Broadband coverage	(2) Urbanization Externalities	(3) Intermediate demand	(4) Human capital
Urban-Rural classification of regions = o,	-	-	-	-
Standard Fixed Broadband Coverage	-0.0945	-0.0987	-0.0867	-0.0914
	(0.0611)	(0.0625)	(0.0613)	(0.0625)
Population Density		-6.40e-05	-1.85e-05	-0.000464
		(0.00239)	(0.00323)	(0.00314)
Next Generation Access Coverage	0.166***	0.165***	0.126**	0.140*
	(0.0553)	(0.0572)	(0.0624)	(0.0727)
Manufacturing Share in total Employment			-0.275***	-0.282***
			(0.0762)	(0.0743)
Regions with Capital Cities = o,	-	-	-	-
Percentage of Population Aged 15-64				0.0600
				(0.125)
Constant	27.49***	27.46***	31.74***	28.05***
	(0.248)	(0.958)	(1.909)	(8.515)
Observations	3,499	3,332	3,044	3,044
Number of NUTS3_ID	1,218	1,148	1,052	1,052
R-squared	0.002	0.002	0.008	0.008

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To define the comparative importance of broadband coverage, groups of control variables were added. The model 2 of the table 13 introduces urbanization externalities captured by the population density. The time invariant variables, such as regions with capital city and urban-rural classification was omitted from the fixed effects model. Including the urbanization externalities in the model did not change the significance of broadband coverage variables, suggesting that urbanization externalities did not explain part of the effect of broadband coverage on KI(B)S. The population density is statistically insignificant, which contradicts the literature reviewed. The possible explanation is that the effect of urbanization externalities is captured with other regressors, which are omitted from analysis due to time-invariance, such as the urban-rural classification of regions and presence of capital city. The model assumes those variables as entity-specific characteristics.

The model 3 in the table 13 introduced the region specific sectoral structure determining intermediate demand on business services captured with the employment share in manufacturing. Adding a new variable did not affected the standard fixed broadband coverage significance, but it decreased both, significance and coefficient of NGA coverage variable, suggesting that part of the effect of main independent variable was related to the control variable. The control variable is negatively related to the dependent variable. As European Commission report regarding Knowledge Intensive Business Services in Europe (2012) suggests, the relationship between manufacturing and KI(B)S varies over regions. The possible explanation of the relationship could be that in some regions manufacturing firms provide those services internally instead of outsourcing and that hinders the development of KI(B)S in those regions (European Commission, 2012). Another possible explanation is that, as Shearmur and Doloreux (2008) suggest on example of Canada, the KI(B)S serving manufacturing clients do not necessarily leave urban and metropolitan areas and still are sufficiently close to their clients. The use of small regional units reinforce this possible explanation. The model explains only 0.8% of the dependent variable.

The model 4 in the table13 introduces the new variable – percentage of population aged15-64, as according to the literature, the level of human capital is important predictor of KI(B)S start-ups. Adding a new variable in analysis decreased the significance of NGA coverage, suggesting that part of the effect of NGA broadband coverage on KI(B)S was related to the level of human capital in regions, as both of them tend to benefit the urban areas, especially regions with capital cities (as mentioned during the explanation of the correlation matrix above).

To summarize, in all of the models in the table 13 the significance and coefficients of main independent variables of interest were stable – the standard fixed broadband did not occur significant in non of the models, while NGA coverage remained significance in conditions of additional variables. Though, the significance of NGA coverage decreased while accounting for manufacturing share in total employment and indicator for human capital, suggesting that the part of the effect of NGA was related to the human capital (most likely in urban regions) and part of the effect was related to the manufacturing sector.

4.2.2. RQ2: Is the regional specialization in KI(B)S sector spatially related to the level of broadband provision in European regions for 2014?

4.2.2.1. Dependent variable

The data of dependent variable was collected from EUROSTAT database, under the section Employment in technology and knowledge-intensive sectors by NUTS 2 regions (NACE Rev.2). Total knowledge intensive services as percentage of overall employment data covers EU28, EFTA and candidate countries and is derived from EU-Labor Force survey for the population aged 15-64. The data of 2014 used in the research is available by NACE rev.2. The knowledge intensity in a sector is based on the level of tertiary educated people employed there (Eurostat, 2016). For analysis two dependent variables were used – KI(B)S share in total employment and Location Quotient to capture the regional specialization. Though, the analysis using location quotient is included in Appendix. The table #14 shows the summary statistics of dependent variables. The mean of employment share is 39.93%, while regional specialization expressed with location quotient is 0.98, which is slightly lower than a number considered as the threshold between specialization and non-specialization (1).

Table 14: summary table of dependent variables for 2014

Variable	obs	Mean	Std.Dev.	Min	Max
Employment share in KI(B)S	291	39.93196	8.971348	14.2	66.8
Location Quotient of KI(B)S	291	0.9851845	0.1509191	0.6108479	2.032483

The figure16 shows the spatial pattern of knowledge intensive business services in European regions. The data mapped exhibits defined spatial pattern: almost north-south, east-west divide is notable, where Nordic and countries of Western Europe perform better then Southern and Eastern country regions. The highest share of KI(B)S in total employment is observed in regions of UK, Sweden, Norway, and Ireland followed by Belgium, Denmark and Netherlands. The lowest level of KI(B)S specialization is mapped in Romanian regions, followed by Greece, Poland and Bulgaria. What is overall, the regions with capital cities dominate. As suggested by European Commission report (2012), capital city regions even in new member states tend to attract local or foreign KI(B)S firms resulting in increased employment share. Examples are the regions of Prague, Bucharest, Bratislava, Budapest, Sofia, and Warsaw. Though, the employment share of KI(B)S in Sofia and Warsaw is comparatively low. Perhaps because of the larger size of the NUTS 2 regions of these capitals, the importance of KI(B)S sector concentrated in central city is weakened by the number of employees in other sectors in the large area of the region resulting in decreased level of KI(B)S employment share in total employment.

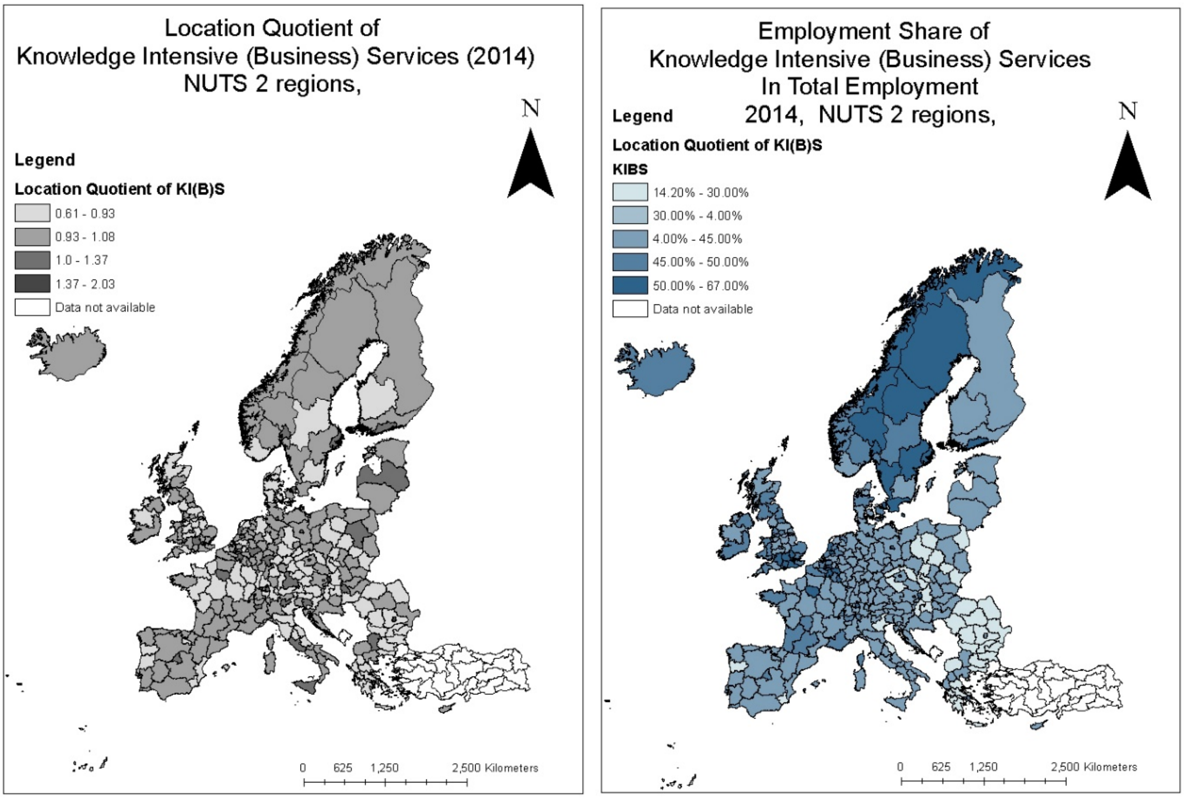


Figure 16: Spatial Pattern of Knowledge Intensive (Business) Services. Source: Author, based on data provided by EUROSTAT

To further evaluate the spatiality of the dependent variable over European regions univariate Global and Local Moran’s I was employed. Hereby we mention that as the main interest of the thesis is to evaluate a the comparative importance of broadband provision for KI(B)S spatial pattern over European regions, the research from now on uses employment share in KI(B)S in total employment as dependent variable. The use of location quotient is not the most proper way, as this measure evaluates how concentrated KI(B)S are in a region as compared to the nation. Though, instead of comparison with the nation, we are more interested to compare regions with each other all over Europe. Thus, the employment share is the most proper measure in this sense.

The Global Moran’s I is a tool of inferential statistics and it measures Spatial Autocorrelation based on locations of features and their values using the Global Moran's I statistic. The method is widely used in different fields. A measure of similarity of data points is plotted as a function of the actual distance between these points (F. Dormann, M. McPherson, et al., 2007).

As The results of Global Moran’s I (included in appendix with explanation of interpretation of results) showed, according to the z-score of the variable, the clustered pattern could not be the result of random chance. The global, overall spatial dependency can be broken down – as the scatterplot is divided into squares. The units located in the 2nd square are the ones with high – above average own and high neighbourhood mean values. On the other hand, units located in the 3rd square are the ones below average own and neighbourhood mean values creating low-low clusters together. The other two squares host spatial outliers – units with high own and low neighbourhood mean values and vice versa (F. Dormann, M. McPherson, et al., 2007).

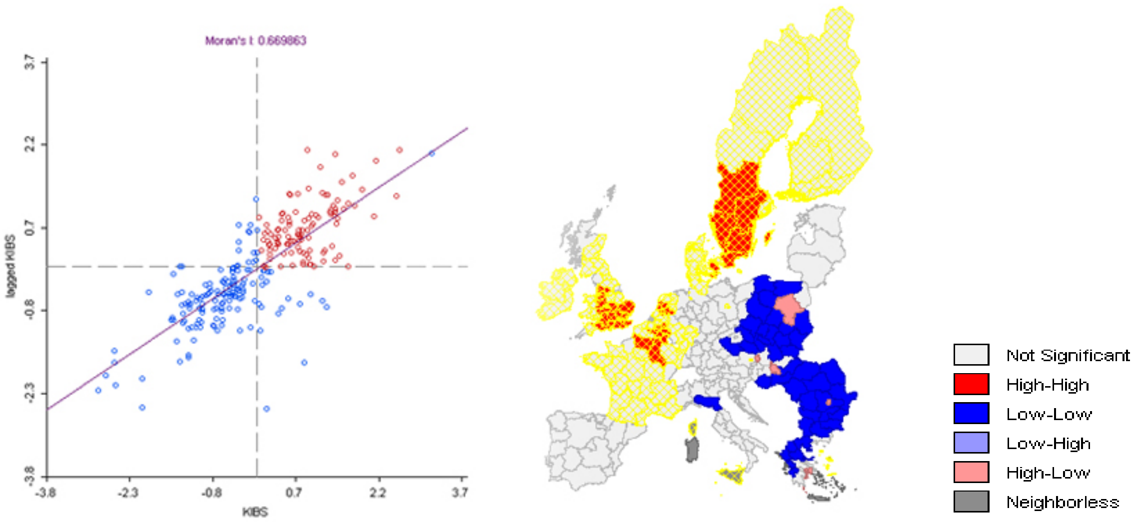


Figure 17: Moran's scatterplot and map of KI(B)S pattern with high-high regions highlighted in yellow on the map and with red color on scatter plot. Source: Author, 2016

The figure 17 shows the regions with high levels of KI(B)S surrounded by the regions with also high level of the dependent variable (marked with yellow grid). As already discussed above, these are mostly regions in Northern and Western Europe – UK, Sweden, Finland, Belgium, Netherlands, France, Western regions in Germany, and Ireland. Though, the statistically significant clustering of high-high values are only the ones colored in red on the map, namely, Sweden, UK, Belgium, Netherlands and a capital city region in Denmark. Respectively, figure 18 shows the regions with low level of KI(B)S employment share surrounded by regions with also lower level of dependent variable, but statistically significant clustering is only established in regions with blue color. As already discussed above, these are mostly regions of southern and eastern Europe, namely, in Poland, Romania, Bulgaria, Greece, and some regions in Czech republic. The high-low outliers (scatterplot and map included in appendix) are mostly capital city regions in Eastern Europe and some regions in the south, suggesting the significant attractiveness of capital cities for knowledge intensive establishments in comparison with other regions.

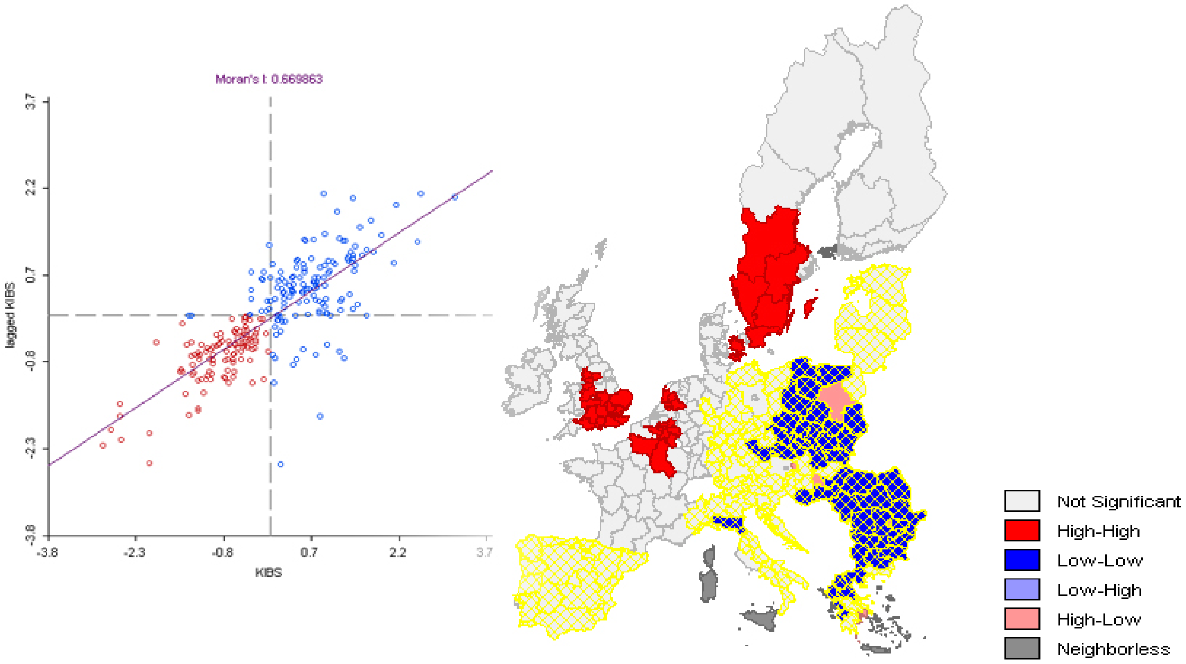


Figure 18: Moran's scatterplot with low-low regions highlighted with yellow grid on the map and respectively, with red color on the scatter plot. Source: Author, 2016.

4.2.2.2. Independent variable

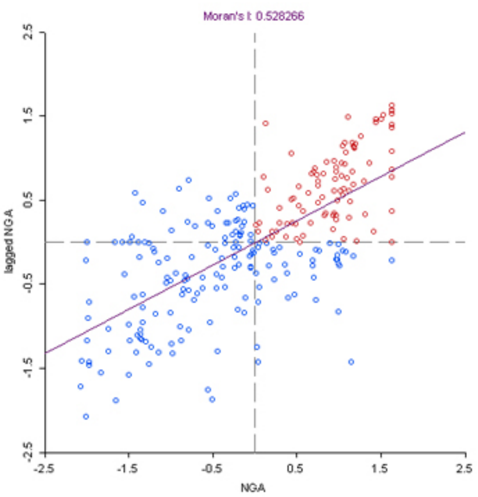
The independent variable was collected from interactive broadband coverage map provided on BRESAT website (www.cip-bresat.eu). The data of this map is obtained from Point Topic, which is one of the leading consultancy companies in this field. The data was for 2014 and on the level of NUTS 3 regions, thus needed to be aggregated at NUTS2 regions level due to the unavailability of dependent variable's data for 2014 at NUTS 3 regions level. Norway, Switzerland, some Croatian regions, Luxemburg and three German regions were excluded from the analysis due to the unavailability of the data.

Broadband coverage data on the interactive map was continuous indicating the number of population having access to NGA or standard fixed broadband technologies. For final analysis the percentage of population having access to these technologies was calculated for each region to capture the infrastructural capital of the region. The table 15 shows the summary statistics for independent variable at NUTS 2 level. One can see that the standard fixed broadband mean is 94.4%, which is much higher than the NGA coverage. The significant differences are between minimum values of each variable. The lowest level of standard fixed technologies coverage is recorded in Poland, the highest – in Belgium, Sweden, Austria, and Greece. In terms of NGA coverage the regions performing the best are in Finland, Belgium, Netherlands, and Portugal, while the lowest values are recorded in Italy.

Stats	Next Generation Access broadband coverage	Standard fixed broadband coverage
Mean	63.465	94.370
N	260	261
Sum	16501.08	24630.42
Max	100	99.998
Min	16.942	77.441
St.D.	22.419	5.21
Skewness	-0.236	-1.381

Table 15: Summary Statistics table for independent variables at NUTS 2 level

To further describe the independent variable Univariate Local Moran's I was used. As the figure 19 illustrates, the regions with high level of NGA coverage by the same type of regions are located in all parts of Europe – Eastern, Western, Northern and Southern (marked with yellow grid), but the statistically significant high-high clustering is only captured in Belgian, Dutch and UK regions and one region in Spain. The results of descriptive analysis suggest the importance of location and proximity for development of network infrastructure – highly connected regions are clustered together, while whole set of regions do not benefit from high level of high quality connectivity and create low-low clusters in the south and east of Europe. The results (included in appendix) of standard fixed broadband coverage was quite interesting: Regions in some countries that perform well in terms of standard fixed broadband coverage, are the ones that have comparatively low level of NGA coverage. These are regions mostly in the south of Europe – Spain, Portugal, Italy, Greece, Romania, Czech Republic, but also in France, meaning that presence of broadband in those countries is no longer an issue, but new technology combinations need further expansion.



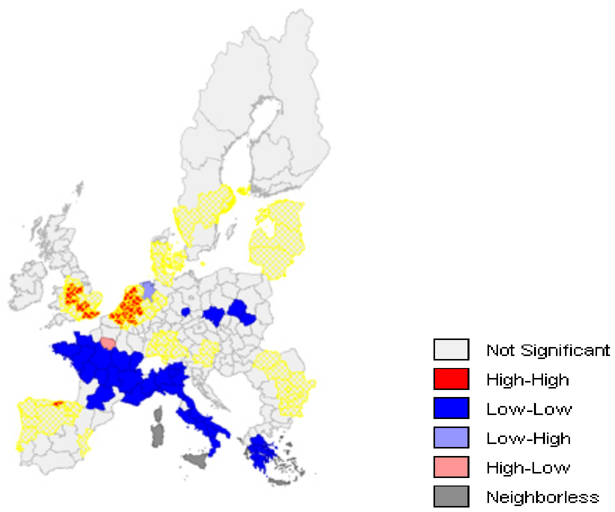


Figure 19: Moran's I scatterplot and cluster map for NGA coverage, indicating high-high regions. Note: the regions with yellow mark are the ones highlighted on the scatterplot. Source: Author, 2016

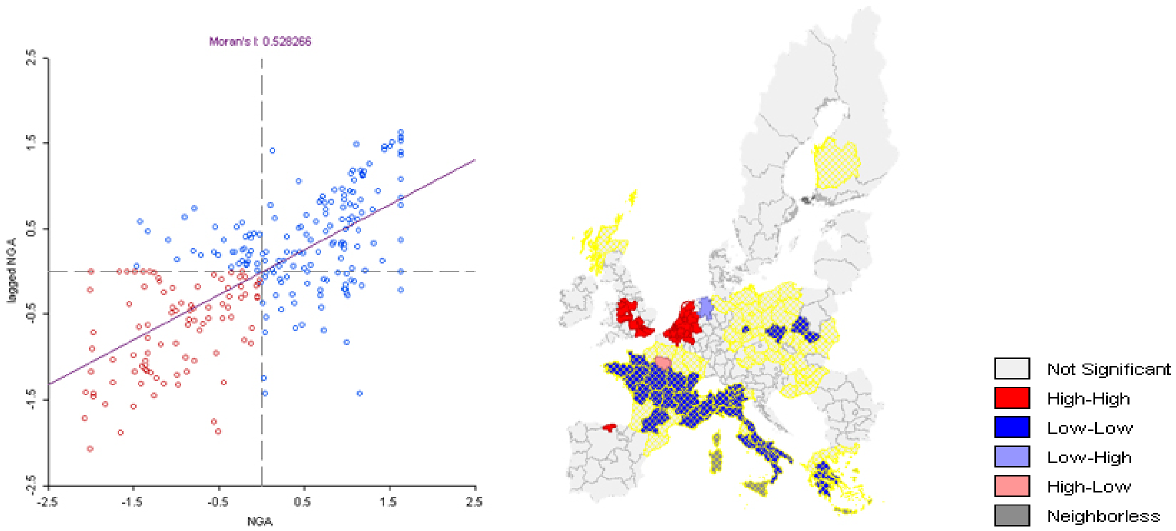


Figure 20: Moran's I scatterplot and cluster map for NGA coverage, indicating low-low regions. Source: Author, 2016

On the other hand, regions in the UK and west part of Germany have lower level of standard fixed broadband coverage and higher level of NGA coverage, suggesting that in these regions the new technology combinations are prioritized. Regions in Countries, such as Belgium and Netherlands perform well– in terms of both technology combinations, meaning that the standard fixed broadband coverage was historically good but specific attention is payed to new technology combinations as well.

4.2.2.3. Control variables

The objective of the analysis is to determine the comparative importance of broadband coverage for knowledge intensive business services while controlling for other groups of factors. Thus, three groups of control variables were introduced. Urbanization externalities are captured by population density, and regions with capital cities dummy variable. Region specific sectoral structure determining intermediate demand is measured with the employment share in manufacturing and high and medium high technology manufacturing. The total intramural R&D expenditure as percentage of GDP is associated to the region specific innovation environment and the percentage of population aged 25-64 with tertiary education captures the level of human capital. The summary statistics of control variables are presented on the table 16. Note, that logarithmic transformations of three variables –population density, R&D expenditure as percentage of GDP and standard fixed broadband coverage – were used in analysis, as histograms of these variables showed skewed distribution (see figures 21 and 22)

Table 16: Summary statistics table for control variables at NUTS 2 level

Variable	Obs	Mean	Std.Dev.	Min	Max
Population Density	286	342.240	790.775	3	7393.4
Regions with capital Cities	283	0.098	0.299	0	1
Employment share in manufacturing	285	14.991	6.902	2.3	35.8
Employment share in high and medium high technology manufacturing	271	5.460	3.569	0.3	19.2
Percentage of population aged 25-64 with tertiary education	290	29.466	9.745	11.4	69.8

Total intramural R&D expenditure as percentage of GDP in 2013	271	1.583	1.313	0.06	11.36

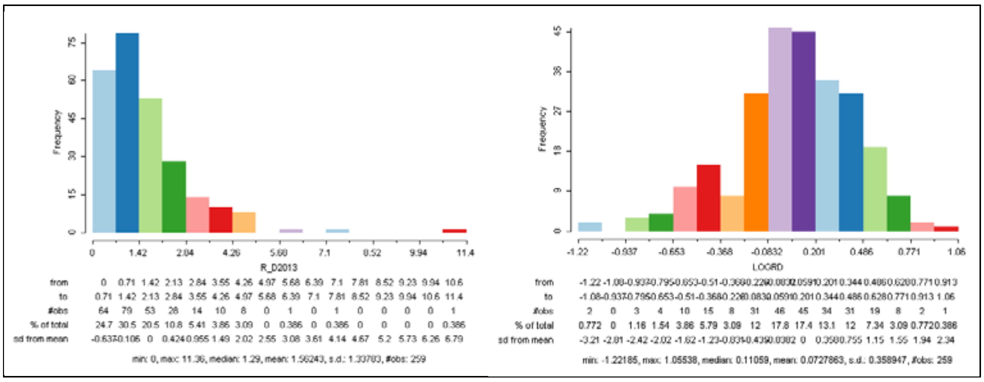


Figure 21: Histograms of total intramural R&D expenditure as percentage of GDP in 2013 and logarithmic transformation of the variable. Source: Author, 2016

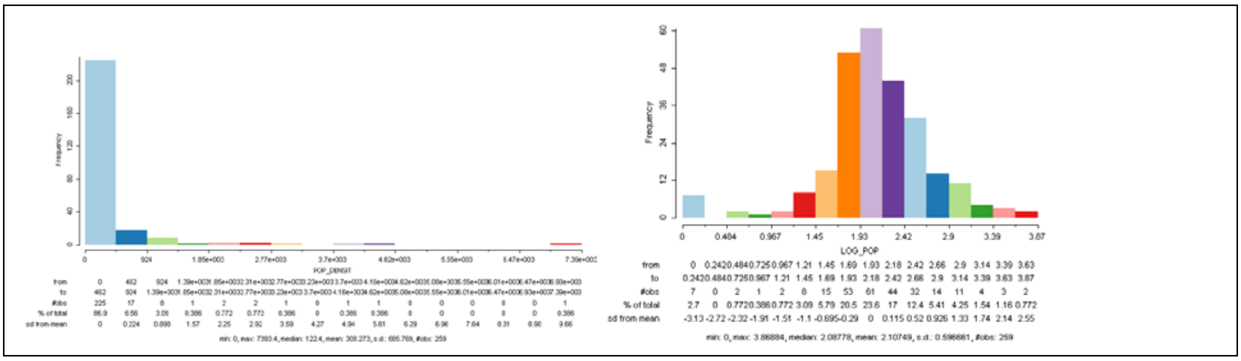


Figure 22: Histograms of population Density and the logarithmic transformation of the variable. Source: Author, 2016

4.2.2.4. Data analysis methods and results

For the first stage of the analysis exploratory spatial analysis techniques were employed using bivariate Local Moran's I to explore spatial relationships between variables. In this case GeoDA software was used, as ArcGIS only provides univariate global and local Moran's I. The local Moran's I allows one to see the regions where the relationship is statistically significant. The significance is based on a random permutation procedure, which recalculates the statistics many times and generates the reference distribution. The resulted statistics is then compared to the reference distribution and pseudo significance level is computed. Note, that the LISA (Local Indicator of Spatial Autocorrelation) maps might be slightly different each time maps are generated, because the calculation of significance is based on random shuffling – permutation which changes each time one runs analysis, though main pattern remains (Anselin, Syabri, et al., 2010).

The results could be calculated in two different ways – whether regions with higher broadband coverage level attract more KI(B)S in neighboring regions and whether the broadband coverage level is higher in regions next to regions with higher KI(B)S employment level, as the relationship between these variables is not unidirectional – broadband providers tend to invest in infrastructure in those regions, where the demand is high and KI(B)S may also locate near regions where the broadband provision is high (Mack, 2014, Mack, Anselin, et al., 2011). The research follows the outline of the US research (Mack, 2014) and tries to figure out whether regions with high (or low) level of broadband coverage were able to increase KIBS share in surrounding regions.

As the software imports missing values on polygons as zeros, the regions for which the data of either KI(B)S or NGA coverage was missing, were deleted not to be included in calculations of neighboring regions. These are Norwegian regions, Luxemburg, Lichtenstein, three German regions, and Switzerland. Before analysis weights file was created based on Queen Contiguity, which means that the weights file uses a common boundary of a common point of features as criterion to define neighbors. Note, that a spatial lag of dependent variable (in this case KI(B)S) was used for this analysis to account for spatial autocorrelation which was confirmed by univariate Moran's I analysis.

The results of bivariate local Moran's I are shown on figure 30. It allows us to see the regions, where the relationship between dependent and independent variables is statistically significant. The results are interpreted as follows:

0) High-high – regions with high level of NGA broadband coverage surrounded by regions with high share of employment in KI(B)S.
1) Low-low – Regions with low levels of NGA broadband coverage surrounded by regions with below average level of KI(B)S employment share
2) Low-high – regions with low level of NGA broadband coverage but still surrounded by regions with high level of KI(B)S employment share.
3) High-low – despite the high level of broadband coverage, regions are surrounded by low level of KI(B)S employment share

The statistically significant high-high clusters occur in the countries of northern and western Europe – Sweden, Denmark, Netherlands, Belgium and two French regions. Particularly, the French high-high regions are located next to the region with capital city, suggesting that broadband was capable to overcome centripetal forces of capital city and allow knowledge intensive business services strategically locate in nearby regions (Mack, Anselin, et al., 2011). The high-high cluster in Sweden, Netherlands and Belgium contains not only capital city, but also other regions. When looking at the map of degree of urbanization (Source: Eurostat, 2016. Included in Appendix), one can see that some of these are regions in Sweden and most of regions in Netherlands and Belgium are with cities (densely populated areas, where at least 50% of population lives in urban centres) suggesting the importance of urbanization externalities, but some of the regions in Sweden are the ones with towns and suburbs (intermediate density areas, where less than 50% of population lives in rural grid cells and less than 50% of the population lives in urban centres) supporting the theories regarding the decentralization power of internet technologies for firm locations.

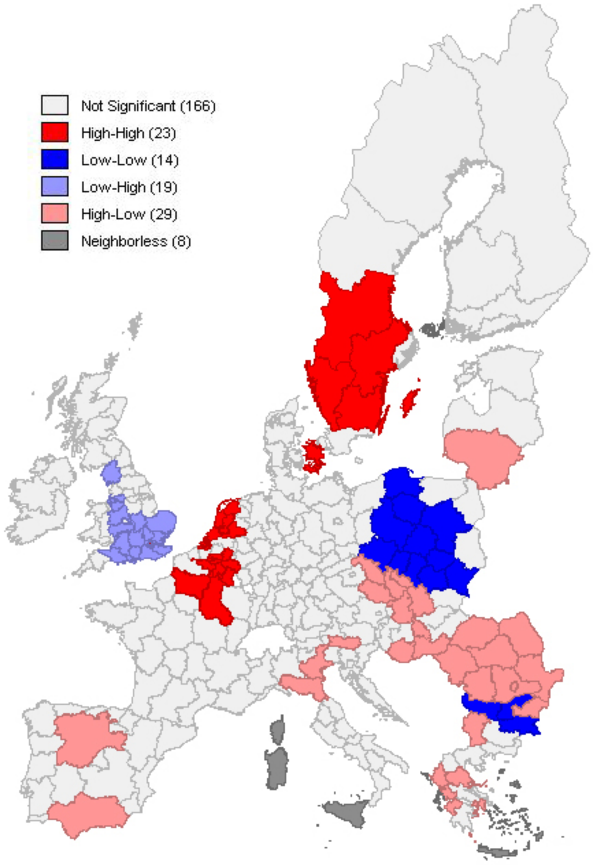


Figure 23: Bivariate local Moran's results map for standard fixed broadband coverage and KI(B)S. Source: Author, 2016

The low-low clusters are the opposite category of the one described above. In those regions both, broadband coverage and KI(B)S level are low. For standard fixed broadband the cluster includes mostly regions in Poland, but for NGA coverage regions of Czech republic, Romania, Hungary, Greece and Slovakia occur in addition to Poland, suggesting that Poland performs bad in terms of broadband as a whole and KI(B)S and even other factors were not able to improve the level of KI(B)S in regions other than capital city. In the rest of countries mentioned above the presence of broadband is not an issue any more, but what makes difference is the advanced technology combinations' coverage.

More interesting types of clusters are low-high and high-low clusters. High-low clusters mainly occur in the southern and eastern Europe, suggesting that the broadband was not able to overcome the centripetal forces of capital city. Existence of this type of cluster supports the theories of centralization power of ICT, which implies that concentration of both, ICTs and firms might be urban-biased and ICTs will reinforce, rather than diminish the importance of urbanization externalities (Mack, 2014, Mack, Anselin, et al., 2011, Gaspar and Glaeser, 1998).

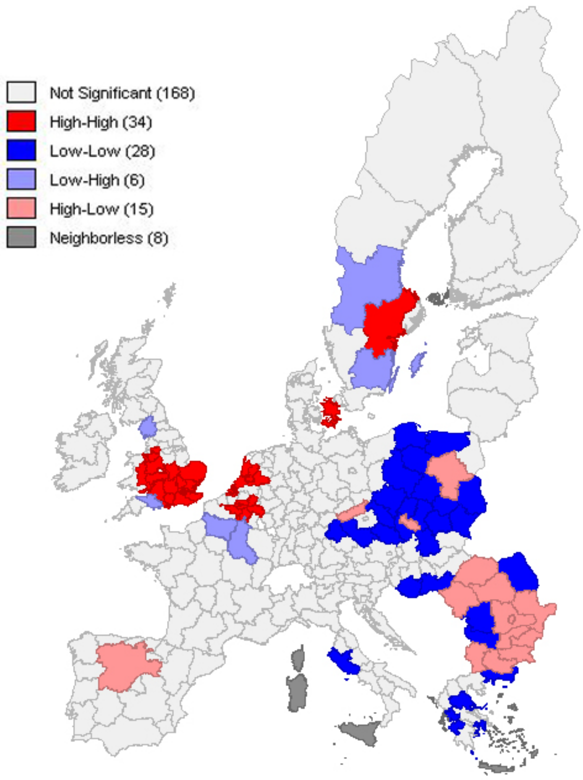


Figure 24: Bivariate Local Moran's I results for NGA coverage and Employment share of KI(B)S. Source: Author, 2016

The low-high clusters are the conceptual opposite of the high-low category. The level of KI(B)S is high, though the standard fixed broadband coverage is comparatively low. These are regions located in UK. One might think, that factors, other than broadband contribute the development of KI(B)S sector, which might be also true, but when looking at the map on the figure 25, we see that these regions in the UK are the ones with high level of NGA coverage. It gives basis to conclude that instead of standard fixed broadband coverage, more advanced technologies coverage might be related to the level of KI(B)S sector development. Though, to evaluate the comparative importance of NGA coverage, additional analysis is needed including control variables. Both, high-low and low-high clusters suggest that factors other than broadband coverage strongly influence the level of KI(B)S and additional analysis is needed.

All and all, the results of exploratory spatial analysis confirmed that the spatial distribution of internet infrastructure is far from being ubiquitous and the impact it generates is differentiated at spatial level (Tranos, 2012). Different types of clusters in different parts of Europe suggest that the relationship between variables might vary through space. To evaluate the regional differences in terms of internet infrastructure's influential power on KI(B)S, sub-regional analysis is needed including control variables.

After exploratory spatial analysis, for the next stage control variables were included to account for other influential factors and define the comparative importance of broadband provision for KI(B)S. For this purpose spatial models should be used instead of OLS due to following reasons: the autocorrelation is proved in the spatial structure of both variables in the previous research question analysis and the use of linear regression in the presence of spatial autocorrelation is related to several problems. First, it generates biased and inconsistent estimators when the model must include a spatial lag of the dependent variable (Anselin, 1988, Mack, Anselin, et al., 2011) or, it can generate unbiased but inefficient coefficients when spatial structure is present in the error term because the variance matrix of the disturbance is heteroscedastic (Anselin, 1988, p.59).

If there is a spatial autocorrelation in regression residuals, spatial error model should be employed, and in case of spatial autocorrelation in dependent variable, spatial lag model should be used. The testing procedure to make choice between a spatial lag (Spatial Autoregressive model (SAR)) and a spatial error models (SEM) is based on the robust Lagrange Multiplier tests developed by Anselin et al. (1988). As a standard approach, mostly spatial analysis is started with a non-spatial linear regression model, as a benchmark, and then test whether it should be extended including spatial interactions. The Lagrange Multiplier test indicated that Spatial Error model best fits the data.

The spatial error model (SEM) allows the spatial dependence in the disturbances. Spatial models can be estimated by maximum likelihood (ML), quasi-maximum likelihood (QML), instrumental variables (IV), generalized method of moments (GMM), or by Bayesian Markov Chain Monte Carlo methods (Bayesian MCMC) (Elhorst, 2013). For this analysis ML estimation method was chosen.

At first, only dependent and independent variables were included in the analysis to determine whether the level of broadband coverage was related to the KI(B)S employment share in regions including spatial dependence. As results of the model 1 of the table 17 shows, both, NGA and standard fixed broadband coverage show positive significant relationship with the employment share in KI(B)S.

Model 2 in the table 17 incorporates group of control variables related to the urbanization externalities. The results show that only the NGA coverage remained statistically significant with positive coefficient equals to 0.951. The effect of standard fixed broadband in previous model was explained with factors related to the urbanization externalities. From control variables the importance of capital city is significant and positive, meaning that the regions with capital cities are more likely to attract the knowledge intensive establishments. This factor seems to me more important than population density, which gradually lost its importance when including other groups of control variables, such as intermediate demand (manufacturing and high and medium high technology manufacturing, employment share), region specific innovation and knowledge environment, and human capital.

The manufacturing and high and medium high technology manufacturing seemed to be significant influential factors for KI(B)S sector development, but when including human capital as additional control variable in the model 4, the significance of high and medium technology manufacturing employment share was diminished, meaning that the human capital level in a region explained the statistical significance of high and medium high technology manufacturing employment share in previous model. It is not surprising, as people employed in high and medium-high technology manufacturing are most likely to be with tertiary education and aged 25-64. The statistically significant negative coefficient of manufacturing share in total employment might have a possible explanation: the manufacturing firms provide the knowledge intensive services internally that decreases the need of outsourcing from knowledge intensive business services (European Commission, 2012)

The comparison of the outcomes demonstrated that the significance of standard fixed broadband was attributed by other factors, but the next generation access broadband coverage is a significant predictor of KI(B)S sector development even when accounting for other factors. The results confirmed that nowadays the presence of broadband is not an issue, but advanced technology combinations still make difference. The comparison of the R squared values for four models demonstrate that adding groups of control variables improved the explanatory power of the models. The significant spatial error coefficient (lambda) indicates that the spatial error model was chosen correctly.

Table 17: ML estimation of spatial error model. Source: Author, 2016

Independent Variable	(1)	(2)	(3)	(4)
NGA Coverage	0.127***	0.951***	0.063***	0.029**
	[0.019]	[0.018]	[0.016]	[0.015]
	(6.518)	(3.079)	(3.777)	(1.945)
Standard fixed broadband coverage	0.232**	0.027	-0.061	-0.014
	[0.109]	[0.101]	[0.089]	[0.079}
	(2.114)	(0.786)	(-0.683)	(-0.180)
Log of Population Density		1.455*	1.079*	0.722
		[0.649]	[0.583]	[0.520]
		(2.239)	(1.849)	(1.387)
Regions with capital Cities		7.870***	5.550***	1.973**
		[1.041]	[0.976]	[0.945]
		(7.557)	(5.687)	(2.086)
Employment share in Manufacturing			-0.578***	-0.350***
			[0.084]	[0.144]
			(-6.813)	(-4.472)
Employment share in High and Medium High Technology Manufacturing			0.313**	-0.032
			[0.153]	[0.144]
			(2.040)	(-0.223)
Percentage of Population aged 25-64 with Tertiary education				0.365***
				[0.050]
				(7.248)
Log of Total Intramural Expenditure on R&D Over GDP				1.744*
				[0.988]
				(1.763)
CONSTANT	9.926***	29.623***	43.956***	31.585***
	[10.429]	[9.597]	[8.616]	[8.030]
	(0.951)	(3.086)	(5.101)	(3.933)
Spatial Error (lambda)	0.753***	0.807***	0.776***	0.743***
R-squared	0.667	0.755	0.802	0.849
N	259	259	259	259

Unstandardized regression coefficients. Standardized regression coefficients in brackets and t-ratios in parentheses

*** p≤0.01, ** p≤0.05, * p≤0.1

4.2.3. RQ3: Does the comparative importance of broadband coverage for development of KI(B)S sector vary across sub-regions of Europe for 2014

The data for the third research sub-question analysis is the same, as for the previous research sub-question. Thus, the data analysis methods and results are discussed directly.

4.2.3.1. Data analysis methods and results

As discussed in the literature regarding internet geography, the impact that internet infrastructure generates, is different in different regions of Europe. Tranos (2012) found almost north-south divide in terms of city-regions ability to utilize internet infrastructure and leverage it to increase the productivity. The analysis in the previous research sub-question also indicated the regional differences of the impact of broadband provision on KI(B)S sector development: different types of clusters occurred in northern, western, southern and eastern Europe, giving the basis to conclude that the developmental role of internet infrastructure differs by sub-regions and the spatial relationships between dependent and independent variables vary.

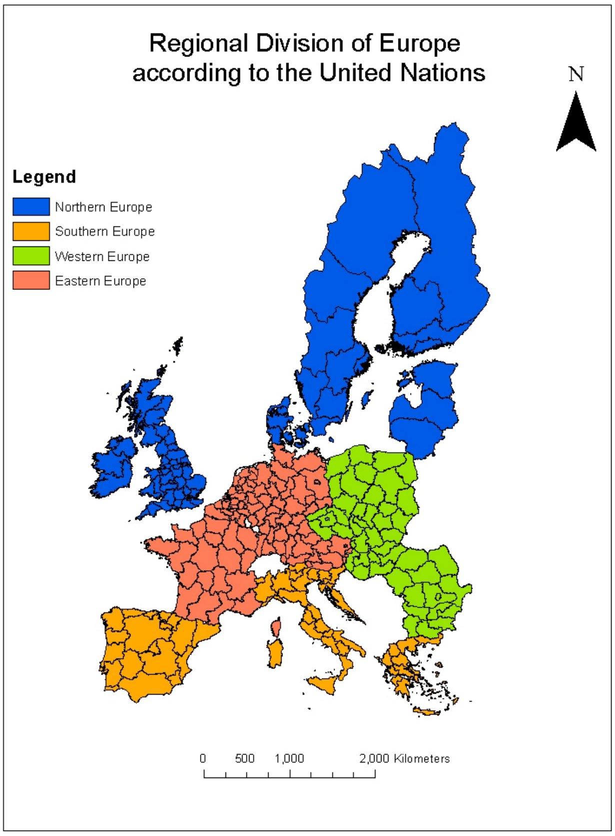


Figure 25: Regional division of Europe according to the United Nations. Source: Author, 2016. Based on (United Nations, 2013). Note: the map only includes units which are used in analysis of this research.

The hypotheses was tested using Spatial Chow test in GeoDaSpace software package. The Spatial Chow test allows to test coefficient stability over different regimes, thus regime dummy was included in the analysis, where 1 stands for Northern, 2 – Southern, 3 – Eastern and 4 – Western Europe, as shown on the figure 25.

The result of overall stability test (shown on table 18) is statistically significant. It means that the null hypotheses, which implies that coefficients are stable across the whole study area, must be rejected. Looking at individual variables of theoretical interest, we see that the results for all of them except Employment Share in High and Medium High technology manufacturing, are statistically significant, which means that their coefficients are not stable across the study area, i.e. the effect of the variables are different in Eastern, Western, Northern of Southern Europe. More importantly, the subject of main interest – NGA coverage shows that its relationship with dependent variable differs by spatial regimes and thus, we need to have a closer look by sub-regions.

Table 18: Stability of Regression Coefficients by Spatial Regime. Source: Author, 2016

	KI(B)S
I. Spatial Chow Test on Overall Stability	298.777***
II. Stability of Individual Coefficients	
CONSTANT	18.620***
NGA Coverage	19.443***
Standard fixed broadband coverage	23.393***
Log of Population Density	11.286***
Regions with Capital Cities	35.473***
Employment Share in Manufacturing	27.633***
Employment Share I High and Medium high Technology Manufacturing	5.222
Log of Total Intramural R&D expenditure over GDP	15.206 ***
Percentage of Population Aged 25-64 with Tertiary Education	23.498***
N(N of North) (N of South) (N of East) (N of West)	259(63) (56) (49 (91)
*** p≤0.01, ** p≤0.05, * p≤0.1	

The unevenness of relationship between variables, i.e. structural instability is present in the data, it may be addressed by switching regression models. When the different subset in the data correspond to different spatial clusters of regions, spatial regimes model is used (Anselin, 1988). Thus, the next step is to actually figure out what model fits best for each regime. According to Lagrange Multiplier test for regime 1 (northern Europe) the spatial lag model is the best appropriate one, for the regime 2 (South) – no significant results indicated that including spatiality is not the best decision. For Regime 3 (East) spatial lag and for regime 4 (West) – Spatial error model occurred to be the best. Based on the Lagrange Multiplier results, for each regime the appropriate spatial model was employed using ML estimation as estimation of spatial models via least squares can lead to inconsistent results of regression parameters (LeSage and Pace, 2009).

The models were run at first without control variables, and then gradually adding control variables group by group. The results on the table 19 show that from independent variables only NGA coverage is significant in all four models, but the standard fixed broadband coverage only becomes significant when controlling for the employment share in manufacturing and high and medium high technology manufacturing. Adding this group of control variables increased the coefficient of NGA coverage as well.

Table 19: Spatial lag model for regime 1 - northern Europe. Source: Author, 2016

Independent Variable	(1)	(2)	(3)	(4)
NGA Coverage	0.219***	0.242***	0.119***	0.111***
	[0.219]	[0.039]	[0.026]	[0.025]
	(5.409)	(6.205)	(4.599)	(4.455)
Standard fixed broadband coverage	0.173	0.228	0.479***	0.431***
	[0.160]	[0.174]	[0.103]	[0.107]
	(1.084)	1.308	(4.633)	(4.034)
Log of Population Density		-1.991***	-0.831*	-0.682
		[0.707]	[0.472]	[0.474]
		(-2.702)	(-1.759)	(-1.439)
Regions with Capital Cities		-2.640	-2.926**	-3.510***
		[2.055]	[1.210]	[1.237]
		(-1.284)	(-2.418)	(-2.836)
Employment share in Manufacturing			-1.409***	-1.267***
			[0.127]	[0.145]
			(-11.081)	(-8.705)
Employment share in High and Medium high technology Manufacturing			1.301***	0.904***
			[0.298]	[0.323]
			(4.355)	(2.798)
Log of Total Intramural Expenditure on R&D over GDP				2.455**
				[1.212]
				(2.025)
Percentage of population aged 25-64 with Tertiary education				0.053
				[0.062]
				(0.843)
Spatial Lag (ρ)	0.252***	0.220***	0.156***	0.129***
	[0.074]	[0.070]	[0.043]	[0.044]
	(3.376)	(3.111)	(3.612)	(2.900)
CONSTANT	3.174	1.904	-0.867	2.768
	[14.403]	[15.900]	[9.287]	[10.813]
	(0.220)	(0.119)	(-0.093)	(0.256)
R-squared	0.420	0.485	0.831	0.847
N	63	63	63	63

*** p≤0.01, ** p≤0.05, * p≤0.1

The strong effect of inclusion of manufacturing as a control variable might suggest the importance of this variable for KIBS. The change of significance of main independent variables suggests that the broadband technologies enabled knowledge intensive establishments locate outside highly urbanized areas but close to their manufacturing clients (Meliciani and Savona, 2015). This is true for Sweden, as additional analysis of spatial dependence between broadband and manufacturing sector development (the map included in appendix) suggests high-high clusters in Sweden in regions with mostly intermediate densely populated or thinly populated areas. Compared to the map on figure 23, these are also regions creating a high-high cluster of broadband and KI(B)S. This spatial analysis can also explain the negative sign of urbanization externalities' group of control variables in final model (4) of the table 19. Surprisingly, the human capital is not statistically significant. The possible explanation is that the effect of this variable is captured with other variables, such as employment share in high and medium-high technology manufacturing.

Table 20: Analysis Results for Regime 2 (Southern Europe). Source: Author, 2016

Independent Variable	(1)	(2)	(3)	(4)
NGA Coverage	0.005	-0.035*	-0.038*	-0.049**
	[0.028]	[0.021]	[0.019]	[0.024]
	(0.189)	(-1.700)	(-1.944)	(-2.054)
Standard fixed broadband coverage	[-0.602]	-1.143***	-1.646***	-1.516***
	(0.486)	[0.377]	[0.435]	[0.440]
	-1.237	(-3.034)	(-3.776)	(-3.439)
Log of Population Density		2.795***	3.257***	2.282
		[1.015]	[0.982]	[1.067]
		(2.752)	(3.316)	(2.137)
Regions with Capital Cities		11.123***	9.570***	8.625***
		[1.844]	[1.782]	[1.808]
		(6.031)	(5.370)	(4.770)
Employment share in Manufacturing			-0.327*	-0.335**
			[0.137]	[0.135]
			(-2.383)	(-2.478)
Employment share in High and Medium high technology Manufacturing			0.191	-0.006
			[0.330]	[0.336]
			(0.579)	-(0.019)
Log of Total Intramural Expenditure on R&D over GDP				5.828**
				[3.012]
				(1.934)
Percentage of population aged 25-64 with Tertiary education				0.030
				[0.077]
				(0.401)
constant	92.911*	141.511***	193.930***	184.171***
	[48.138]	[36.550]	[42.453]	[43.132]
	(1.930)	(3.871)	(4.568)	(4.269)
R-squared	0.035	0.528	0.617	0.650
N	56	56	56	56

Unstandardized regression coefficients. Standardized regression coefficients in brackets and t-ratios in parentheses

*** p≤0.01, ** p≤0.05, * p≤0.1

The results for regime 1 are in line with the theories regarding the decentralization power of ICTs. Mack (2014) on example of US metropolitan areas argues that broadband in regions with strong manufacturing legacy might be a key element for diversifying the area of industrial base. Though, these areas do not benefit from agglomerative externalities, they are strategically located in terms of transportation accessibility and have lower costs of doing business then major urban centers (Mack, 2014).

The results of analysis for the southern Europe (on table 20) are different. Here the broadband variables only become significant when control variables are included. The negative sign of both main independent variable and positive significant high coefficient of capital city region variable indicates the strong influential power of capital city as attractor of KI(B)S in the southern Europe. It is interesting to note that the population density became nonsignificant when human capital and region specific innovation and knowledge environment variables were included, meaning that densely populated urban areas are also attractors of human capital, which occurs important for Knowledge intensive sector development. The results of analysis in south suggest that broadband is necessary, but not enough condition only itself for knowledge intensive business services sector development (Mack, 2014).

The results for Eastern Europe on table 21 revealed nonsignificant relationship between both variables of broadband coverage and knowledge intensive business services. The most influential factor occurs to be the human capital. Inclusion of this variable made the factor of capital city nonsignificant, which was stably important in other models. It suggests that the factor of capital city is increasingly important in terms of attracting human capital which occurs to be crucial for KI(B)S development. The presence of large low-low cluster of human capital and KI(B)S consisting mostly of Romanian regions located remote from the capital city (as shown on the map included in appendix) confirmed that in the context of Eastern Europe the broadband was not able to overcome the negative externalities, such as a low level of human capital, in regions remote from capital cities. The results of regime 3 suggests that ICTs are necessary but not sufficient condition for KI(B)S development while other essential factors matter. The results also suggest that the extent to which technologies are leveraged to make change in something else, such as KIBS sector development, is determined by the absorptive capacity of a region primarily associated to the level of human capital (Tranos, 2012). The low-clusters human capital indicates the lower level of absorptive capacity, and respectively, low ability of a region to use these technologies for attracting KI(B)S sector.

The results for the Western Europe in model 1 on table 22 showed positive significant relationship between NGA, Standard fixed broadband coverage and KI(B)S spatial pattern, though, while controlling for urbanization externalities, the effect of NGA coverage disappeared, meaning that in the western Europe, generally, the impact of NGA coverage on KI(B)S was explained with urbanization externalities. It suggests, that mainly urbanized areas which benefit from new technology combinations coverage are also the successful ones in terms of attracting KI(B)S. On the other hand, adding urbanization externalities as control variables in model 2 on table 22 did not affect the significance of standard fixed broadband suggesting that other than highly urbanized areas also benefit from standard fixed broadband technologies and that makes difference. While controlling for manufacturing share in total employment in model 3, the influence of standard fixed broadband was decreased as well. The manufacturing share in total employment is negatively associated with KI(B)S. A good example to illustrate this relationship is the large high-high cluster of manufacturing share in total employment in the eastern Germany with also low level of broadband coverage (maps of auxiliary analysis are provided in appendix). Those are the same regions which create a low-low KI(B)S cluster. This suggests that the existing level of broadband was not capable to play its role in terms of sectoral diversification of regions. The high level of manufacturing specialization but low level of KI(B)S might suggest that instead of outsourcing the manufacturing firms located there provide those services internally (Meliciani and Savona, 2015, European Commission, 2012).

Table 21: Spatial lag model for regime 3 - Eastern Europe. Source: Author, 2016

Independent Variable	(1)	(2)	(3)	(4)
NGA Coverage	0.118	0.011	0.014	0.013
	[0.080]	[0.051]	[0.053]	[0.049]
	(1.475)	(0.217)	(0.267)	(0.264)
Standard fixed broadband coverage	-0.043	-0.071	-0.073	0.179
	[0.139]	[0.089]	[0.102]	[0.122]
	(-0.310)	(-0.799)	(-0.715)	(1.465)
Log of Population Density		3.678	3.462	1.450
		[2.512]	[2.649]	[2.388]
		(1.463)	(1.307)	(0.607)
Regions with Capital Cities		14.118***	13.703***	1.170
		[2.594]	[2.957]	[4.137]
		(5.442)	(4.633)	(0.282)
Employment share in Manufacturing			-0.070	0.026
			[0.205]	[0.179]
			(-0.345)	(0.146)
Employment share in High and Medium high technology Manufacturing			0.075	-0.122
			[0.310]	[0.295]
			(0.241)	(-0.414)
Log of Total Intramural Expenditure on R&D over GDP				3.215
				[2.309]
				(1.392)
Percentage of population aged 25-64 with Tertiary education				0.645***
				[0.201]
				(3.199)
Spatial Lag (ρ)	0.443***	0.563***	0.564***	0.423***
	[0.155]	[0.122]	[0.123]	[0.125]
	(2.856)	(4.584)	(4.583)	(3.362)
CONSTANT	13.926	10.203	11.695	-16.047
	[11.705]	[10.378]	[12.328]	[15.945]
	(1.189)	(0.983)	(0.948)	(-1.006)
R-squared	0.176	0.682	0.683	0.763
N	49	49	49	49

*** p≤0.01, ** p≤0.05, * p≤0.1

All and all, the final model on table 22 suggests that in the western Europe the broadband coverage is not a significant predictor for KI(B)S sector development. On the other hand, there is a positive impact of human capital on KI(B)S and a significant negative relationship between KI(B)S and manufacturing. This suggest that the development of knowledge intensive sector in those regions is related to factors other than intermediate demand from manufacturing clients (Meliciani and Savona, 2015). The statistically non-significant main independent variables suggest that broadband is essential but not sufficient factor only itself for KI(B)S sector development. The model R squared is 0.855 and the significant spatial error (lambda) suggests that the model was chosen properly.

Table 22: Spatial error model results for regime 4 (Western Europe). Source: author, 2016

Independent Variable	(1)	(2)	(3)	(4)
NGA Coverage	0.070***	0.014	0.018	0.005
	[0.029]	[0.033]	[0.251]	[0.021]
	(2.392)	(0.448)	(0.729)	(0.271)
Standard fixed broadband coverage	0.651***	0.554***	0.201	0.072
	[0.209]	[0.199]	[0.174]	[0.148]
	(3.113)	(2.775)	(1.156)	(0.485)
Log of Population Density		3.096***	2.272	1.011
		[1.463]	[1.148]	[1.003]
		(2.115)	(1.977)	(1.007)
Regions with Capital Cities		0.955	-0.983	-1.115
		[2.063]	[1.609]	[1.364]
		(0.462)	(-0.611)	(-0.817)
Employment share in Manufacturing			-0.813***	-0.566***
			[0.108]	[0.100]
			(-7.470)	(-5.618)
Employment share in High and Medium high technology Manufacturing			0.543***	0.259
			[0.184]	[0.164]
			(2.947)	(1.574)
Log of Total Intramural Expenditure on R&D over GDP				-0.071
				[1.195]
				(-0.059)
Percentage of population aged 25-64 with Tertiary education				0.347***
				[0.066]
				(5.246)
CONSTANT	-23.681	-18.390	25.269	29.309
	[19.248]	[18.441]	[16.416]	[14.021]
	(-1.230)	(-0.997)	(1.539)	(2.090)
Spatial Error (lambda)	0.734***	0.713***	0.676***	0.686***
R-squared	0.612	0.646	0.793	0.855
N	91	91	91	91

*** p≤0.01, ** p≤0.05, * p≤0.1

Chapter 5: Conclusions and recommendations

5.1. Conclusions

There is a widespread discussion regarding the developmental role of information and communication technologies in the era of digital economy. Though, the question of how these technologies affect the economic activities in space, is not answered fully yet. It is conditioned by the elusive and complex nature of the ICTs – some authors compare it to a "black box", which is hard to unbundle by layers and harder to explore. Some authors note that "telecommunications infrastructure only becomes visible when it stops working" (Tranos, Reggiani, et al., 2013, p.2).

Giving the status of General Purpose Technology (GPT) it provides downstream complementarities, new business models and opportunities facilitated with virtual interaction that enables firms gain a competitive advantage and access the market across the globe (Tranos and Mack, 2015, Tranos, 2012, Mack, Anselin, et al., 2011). But, not surprisingly, both, these technologies and the advantages that they create, are not even – not all people, places and businesses benefit equally from it and the digital divide present between places different from each other by economic, social, locational factors. Thus, the impact it generates is differentiated spatially (Malecki, 2002, Tranos and Gillepsei, 2009b, Mack, Anselin, et al., 2011, Vinciguerra, Frenken, et al., 2011, Vinciguerra, Frenken, et al., 2010).

The main directions of theories regarding the impact of ICTs on firm location suggest three possible outcomes: centralization, decentralization and heterogeneous, as discussed in the literature review in more details. The purpose of this study is to analyze the role of broadband, as main part of ICTs, for knowledge intensive business services in spatial context, as these firms are most likely to be intensive users of these technologies and the nature of their activity is perceived to be more "footloose" in terms of location decisions.

While studying the impact of broadband on KI(B)S spatial pattern is necessary to consider other factors which also might affect the spatial pattern of KI(B)S. Based on the literature review several groups of factors were identified: urbanization externalities, region specific sectoral structure determining intermediate demand, and region specific innovation and knowledge environment (including human capital) (Meliciani and Savona, 2015, European Commission, 2012). Thus, in order to isolate the impact of broadband provision on KI(B)S these groups of factors were included in quantitative secondary data analysis. The consideration of space while studying the relationship is crucially important for this research, as previous studies across the United States (Mack, 2014, Mack, Anselin, et al., 2011) confirmed that space may be effectively incorporated within econometric evaluation of the relationship between broadband provision and knowledge intensive establishment locations.

To determine the comparative importance of broadband provision for KI(B)S spatial pattern in European regions, various research techniques were applied. At the first stage Fixed effects model was used with three years panel data including main dependent, independent and abovementioned groups of control variables. For the second stage, exploratory spatial analysis techniques were used, including univariate and bivariate global and local Moran's I to see the spatial relationship between level of broadband provision and knowledge intensive sector development. At the final stage, spatial error and spatial lag models were employed in different parts of European sub-regions based on the Lagrange multiplier test, which allows one to define which model fits best the data.

As a whole, the research supports the school of thoughts of heterogeneous impact of ICTs on firms location. Those theories state that not only the spatial pattern of internet infrastructure is uneven (as the analysis of univariate local Moran's I confirmed) but also the impact it generates is spatially differentiated (Mack, 2014, Mack, Anselin, et al., 2011). Thus, the comparative importance of broadband for knowledge intensive business services is different for the eastern, western, northern and southern Europe.

The overall analysis using the panel data of three years revealed the nonsignificant relationship between standard fixed broadband but the Next Generation access coverage occurred to be statistically significant. That result is in line with the literature (Mack, 2014, Mack, Anselin, et al., 2011) which states that nowadays the presence of broadband, mainly, is not an issue any more, but the disparities among regions in terms of coverage of advanced technology combinations still makes significant difference.

The exploratory spatial analysis approach showed noteworthy implications. Firstly, it confirms that the relationship between broadband provision and knowledge intensive firms is not homogeneous through space, in fact different types of clusters occur in different parts of Europe. The high-high bivariate local Moran's clusters are mainly presented in Sweden, Netherlands, Belgium, Denmark and France. The high-high cluster in Netherlands and Belgium contain regions with densely populated areas, where at least 50% of population lives in urban centers, confirming the importance of urbanization externalities for both, broadband coverage and knowledge intensive business services. On the other hand two French and some regions in Sweden next to the capital cities but with low degree of urbanization (map included in appendix) support the theories regarding the decentralization power of ICTs. Here ICTs are capable to overcome the centripetal forces of capital city and enable firms strategically locate in nearby regions without high costs of the urban centres. The spatial lag model in the northern sub-region of Europe actually confirmed the importance of ICTs even in comparison of other groups of factors, such as urbanization externalities.

On the other hand, high-low types of clusters, mainly in the eastern Europe suggest that factors other than broadband are important for development KI(B)S sector and these technologies are necessary but not sufficient factor only itself (Mack, 2014). The results of further spatial analysis including control variables confirmed abovementioned statement – neither standard fixed and nor NGA broadband coverage had significant impact on KI(B)S, but human capital, which tend to concentrate in capital city, while remote regions create a vast low-low cluster of it. The results confirm that the developmental role of interne infrastructure are conditioned by the absorptive capacity of a region, for which the human capital, in fact, is crucially important (Tranos, 2012).

The low-high clusters are conceptual opposite of high-low types. Low-high cluster of standard fixed broadband and KI(B)S in UK, also suggesting that factors other than standard fixed broadband coverage are significant. The bivariate local Moran's I revealed that these regions actually created the high-high clusters of NGA and KI(B)S. these results suggest that advanced technology combinations are more important and need to be emphasized. The exploratory analysis results were confirmed with the results of Spatial lag model – broadband coverage variables occurred to be statistically significant and positive. The negative association of capital city and urbanization externalities are in line with the theories that suggest the decentralization power of ICTs, which enables businesses locate outside costly urban areas. In those regions broadband is not a complement, but a substitute of mean of face-to-face interaction (Gaspar and Glaeser, 1998).

5.2. Recommendations

5.2.1. Policy recommendations

The results of the study might be a foundation for several recommendations for policy makers. Firstly, the significance of NGA coverage in most of the time suggests that policy makers should be more concerned about advanced technology combinations deployment, then the standard ones and it should be prioritized in strategic plans. Policy makers are able to facilitate the deployment of the telecommunications infrastructure by studying, mapping the demand and make this information accessible for private telecommunications companies the activity of which is primarily demand driven.

The results of the study suggest that impact of internet infrastructure on KI(B)S is not homogeneous, and in different parts of Europe the effect only occurs while other factors enable it to happen. One of the most important factor that actually determines whether ICTs can have a significant impact, is the level of human capital, which, in fact, is related to the absorptive capacity of a region. Thus, policy makers should prioritize the deployment of hard infrastructure while being concerned about the capabilities of a region to actually utilize the infrastructure.

5.2.2. Recommendations for further research

The results of the research contribute to the existing knowledge on the relationship between ICTs, internet infrastructure as main part of ICT, and Knowledge intensive business services, as intensive users of these technologies in the regions of Europe. The results of the study give several important remarks for further researches. Firstly, the way in which the broadband coverage is indicated in the research, considers the percentage of households for which standard fixed or NGA technologies are available. Further researches may consider more precise measures to capture the impact of particular technology combinations, such as, DSL, VDSL, cable modem, WiMAX and FTTP coverages. The data of separate technology coverage exists, but is not publicly available, which was a restriction for this research. Further researches might include a variable as well, which indicates the degree to which a region is ready for advanced technological extensions. For example, a technology combination might be accessible in a region but households would not be willing to subscribe. The variable that indicates the share of service take-up in services available, might be a good indication for policy makers as well (Soldi, Cavallini, et al., 2016).

The manner in which the dependent variable, KI(B)S, is measured, might be different in further studies. For example, further studies might explore in details for which – financial or computer related business services – is the broadband coverage most important and to what extent it shapes the spatial pattern of dependent variable. Different measures might be used to capture the urbanization externalities, region specific sectoral structure and region specific innovation and knowledge environment, as well.

The further extensions of the study might be concerned about the impact of broadband on KI(B)S at different spatial level – NUTS 3, urban, or intra-urban - to compare how the ICTs role differ at different spatial level and how spillover effect and spatial association works at different scales. Analysis at smaller scale might be more precise and allow one to capture, how ICTs allow firms strategically locate nearby main urban centres without necessarily high costs. Smaller scale of analysis, such as NUTS 3 regions level, would enable one to incorporate a variable indicating access to the city. A subject of particular interest might be predominantly rural and intermediate regions, where urbanization externalities are not presented.

Finally, the results of this study highlights the need of spatial econometric rather than a non-spatial approach. Further researches might incorporate time in addition to space in analysis. The Geographical and Temporal Weighted Regression (GTWR) (Fotheringham, Crespo, et al., 2015) would allow one to observe whether the developmental role of ICTs is sustainable over time of it fades away after reaching certain level.

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Annex 1: Fixed effects model using Location Quotient of KI(B)S as dependent variable

VARIABLES	(1) Location Quotient
Urban-Rural classification of regions = o,	-
Standard Fixed Broadband Coverage	-0.0116***
	(0.00433)
Population Density	-2.24e-05***
	(6.56e-06)
Next Generation Access Coverage	0.0143***
	(0.00456)
Manyfacturing Share in total Employment	-0.00272
	(0.00287)
Regions with Capital Cities = o,	-
Percentage of Population Aged 15-64	0.0373***
	(0.00611)
Constant	-1.522***
	(0.415)
Observations	3,215
R-squared	0.024
Number of NUTS3_ID	1,086

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

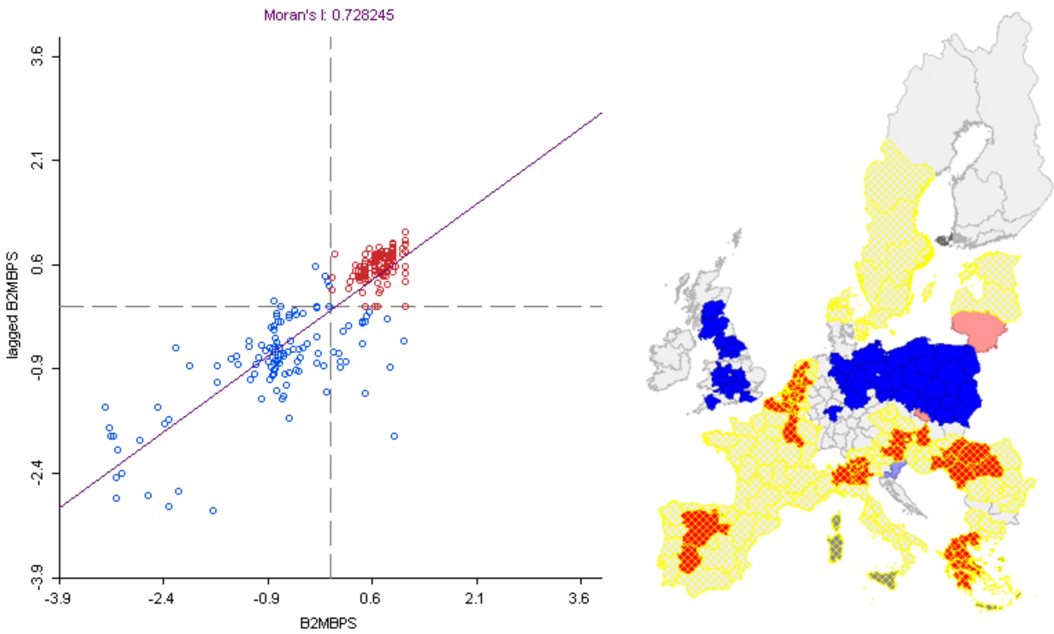
Annex 2: Fixed Effects model with influential points

VARIABLES	(1) Employment Share of KI(B)S in Total Employment
Urban-Rural classification of regions = o,	-
Standard Fixed Broadband Coverage	-0.443***
	(0.160)
Population Density	0.000189
	(0.000244)
Next Generation Access Coverage	0.582***
	(0.165)
Manyfacturing Share in total Employment	-0.123
	(0.100)
Regions with Capital Cities = o,	-
Percentage of Population Aged 15-64	0.921***

	(0.216)
Constant	-31.66**
	(14.74)
Observations	3,215
Number of NUTS3_ID	1,086
R-squared	0.014

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

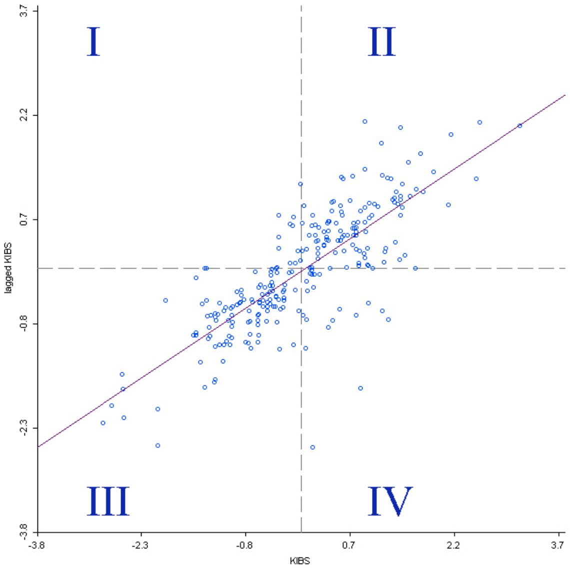
Annex 3: Scatterplot and cluster map of KIBS using univariate local Moran's I



Annex 4: Global Moran's scatterplot, results and explanation for interpreting the results.

The Moran's I index is positive, which means that higher values tend to cluster with higher values and lower values tend to cluster together (ESRI, 2016). The statistically significant p value and positive z score for all variables indicate that we may reject the null hypothesis which implies that the spatial pattern is random and in addition conclude that the spatial distribution of high values and/or low values in the dataset is more spatially clustered than would be expected if underlying spatial processes were random (ESRI, 2016).

The Scatter plots of spatial autocorrelation were produced in GeoDa software. They further illustrate the results generated in ArcGIS. The slope for the variable of interest indicates presence of spatial dependence. On the X axis the values of each unit is plotted, while on the Y axis mean of the neighbourhood values is plotted. In this case, neighbourhood is defined according to the spatial weights matrix generated by us which is based on queen first order contiguity (Anselin, Syabri, et al., 2010).



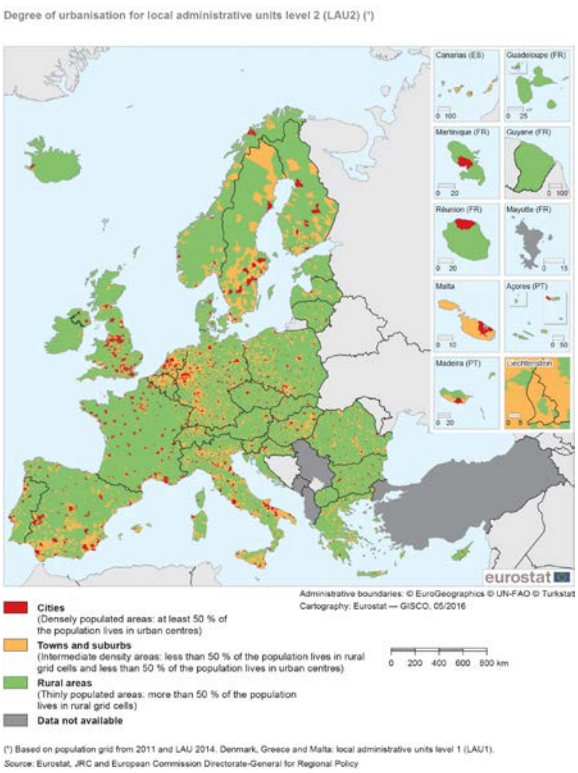
Global Moran's I Summary

Moran's Index:	0.673096
Expected Index:	-0.003448
Variance:	0.001851
z-score:	15.726309
p-value:	0.000000

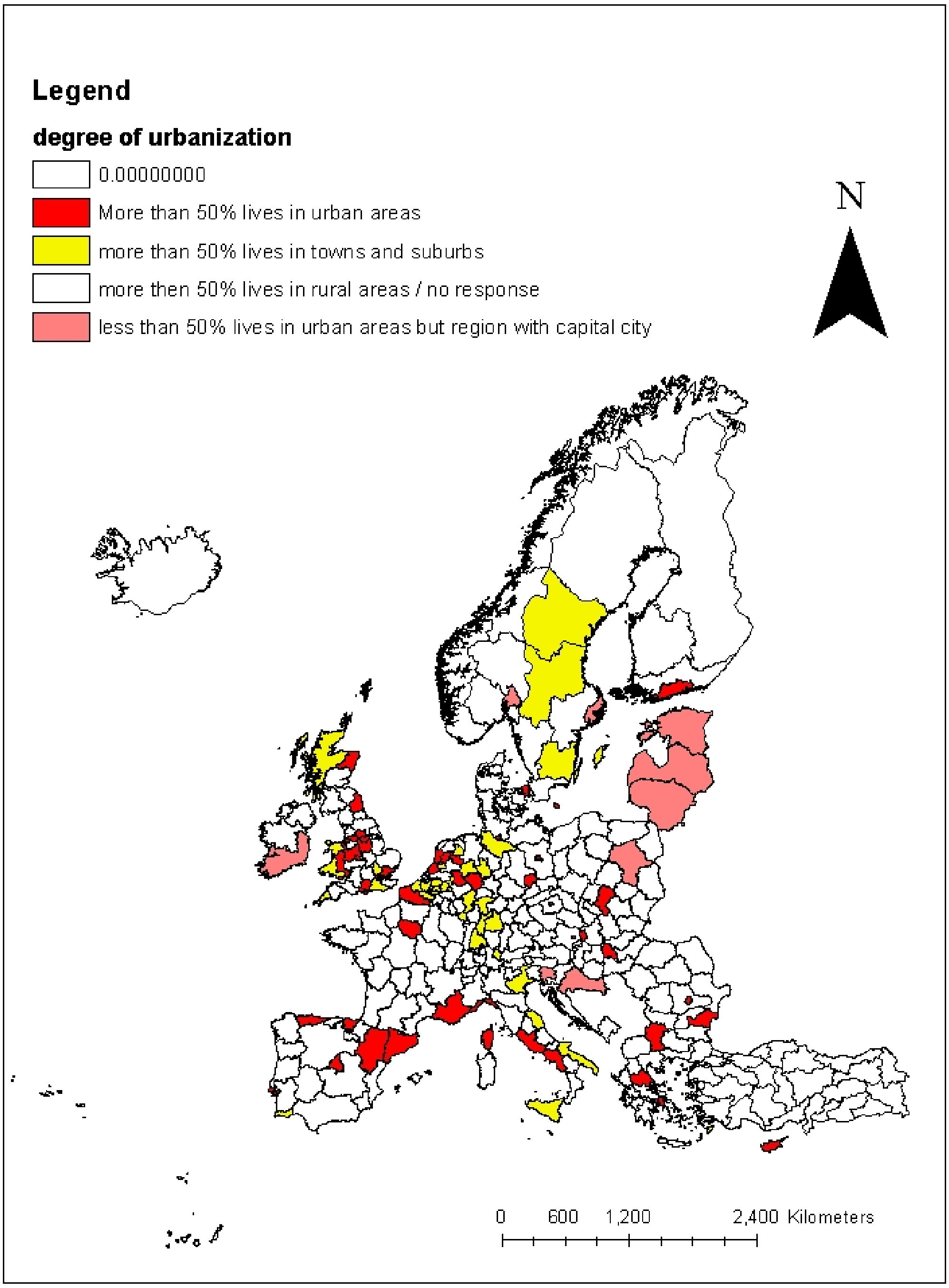
Given the z-score of 15.7263088152, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Figure 26: Global Moran's I scatterplot (GeoDa output) and results (ArcGIS output) for KI(B)S employment share. Source: Author, 2016

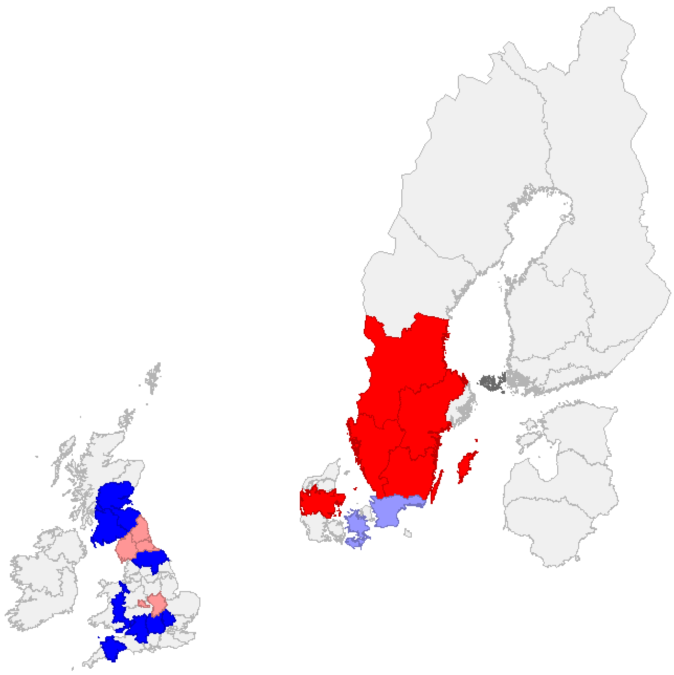
Annex 5: degree of urbanization. Source: Eurostat



Annex 6: degree of urbanization. Source: Author, based on data of Eurostat

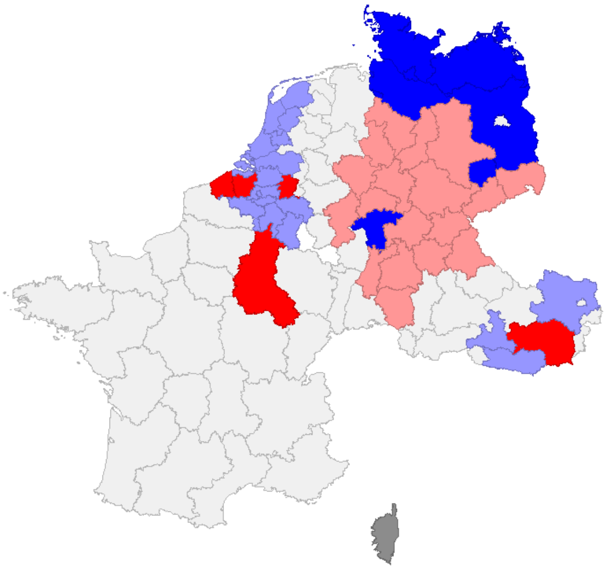


Annex 7: Standard fixed broadband coverage and manufacturing share in total employment. Auxiliary Bivariate Local Moran's I analysis results for regime 1



Annex 8: KIBS and Human capital. Results of Auxiliary bivariate local moran's I analysis for east Europe

Annex 9: Manufacturing and standard fixed broadband coverage. Results of Auxiliary bivariate local moran's I analysis for west Europe



Annex 9: Manufacturing and KIBS. Results of Auxiliary bivariate local moran's I analysis for west Europe