The Internet of Things

Projects – Places – Policies

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ABSTRACT

Since the late 2000s, the Internet has been no longer a global network of billions of connected computers and mobile phones, but rather a growing network of hundreds of billions of intelligent devices and systems for the smart home, smart city, smart industry and connected car applications, to name just a few. In its essence, the IoT age represents an undergoing phenomenon wherein economic and everyday activities are operating as a constant intertwining of the physical and the digital worlds. The ongoing transition from the Internet age to the Internet of Things age is a paradigm shift of knowledge production and interactions, so information and knowledge can be produced and disseminated either without or with very little human interventions. Non-human actors are given cognitive abilities, and thus, they are joining with humans to become the producers and carriers of knowledge, including of the more tacit type of knowledge. This qualitative change calls for re-conceptualising the multilevel knowledge dynamics that integrates the local-global and digital-physical dimensions.

In the local-global dimension, this thesis approaches the geography of context in two ways. First approach is to see context as the spatial configuration of knowledge and innovation networks. The second is to view it as the spatial configuration of local/regional specialisations to the globalisation processes. In the digital-physical dimension, the geography of context is understood through the geography of information, and information society literature. The multilevel dynamics of knowledge-intensive activities underpin both the local-global and digital-physical dimensions. The thesis, thus, combines the geography of information with the geography of knowledge and innovation to build an economic-geographic theory of context for IoT and thereby enhances our understanding of the spatial characteristics and consequences of adopting IoT technologies in society.

The popular notion of IoT as connecting anything from anywhere at any time suggests a return to the “end of geography” debate. This dissertation argues that these spaceless sentiments of IoT are indeed exaggerated and even misleading. Although the emphasis on things by using the term the “Internet of Things” captures its technological novelty - “without or with less human-intervention”, that does not mean that human aspects are now totally irrelevant. On the contrary, the successful realisation of IoT is not about linking anything at any place, but rather to connect something at some place(s) for potential users. Things, places, and people are inherently spatial constructs. This thesis explores those underlying spatially embedded mechanisms in projects and places, including the policies that address the emerging IoT issues.

The thesis concludes that context can affect the production of IoT applications through various aspects in the spatial structure of knowledge and innovation

networks. Regions and places can be test-beds for developing IoT applications because knowledge and policy networks take a long time to develop. Knowledge-intensive activities are at the core of the activities that are taking place on a multilevel geographical scale, where local presence and international reach through contacts and clients are essential for knowledge transfer. The adoption of IoT services is affected by contextual factors of social-economic conditions on different geographical levels, ranging from the individual/households level (e.g., being cool and bringing convenience), the organisational level (e.g., increasing actual productivity and reducing costs), to the societal level (e.g., tackling societal challenges such as sustainable transportation/manufacturing or an aging populations, even food security or improvement in well-being for individuals).

The adoption of IoT technologies can redefine the contexts of specialisation. Automation and telematics can change the production and interactions of information and knowledge by including non-humans as the active actors in a more flexible network across geographical scales. This change is called the *contextuality of relevance and connectivity*, and it re-organises the division of labour and the actor's networks. As a result, it can affect the spatial evolution of local/ regional specialisations to the globalisation processes. New types of proximity may have an impact on the spatial re-configurations of these networks, e.g., *information network proximity* and *information system proximity*. The rise of the IoT age has the potential to enhance the "context-based" specialisation of tasks. In such scenario, the future competitiveness may rely on how much a firm, a region, or a nation is able to relate its specialisation to the "distributed contexts" and how well these entities can generate knowledge and innovation from a "context-based" coordinating and motivating of economic actions.

Keywords: Internet of Things, digital service development, knowledge-intensive business services, EU ICT policy, smart public bike sharing, geography of knowledge, digital economy

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CONTENTS

List of Articles

Article No.	Publication Status	Author(s)	Article Title	Research Question(s)	Empirical Case(s)	Major Findings
Article 1	Published in *The Amfiteatru Economic Journal* 14(6): 698–720. 2012.	Xiangxuan Xu	Internet of Things in Service Innovation	What is IoT in the service innovation context and its spatial ramifications?	The case of China emerging IoT city: Wuxi	The paper defines IoT in the service and innovation context. It points out that the key value of IoT applications is to provide useful information and valued services to potential users. Innovation in services is enabled by automation and telematics. IoT service activities are place-rooted within complex local, global agents' frameworks. Local factors play an important role in the emergence of the Chinese IoT City, Wuxi.
Article 2	Published in Jones A, Ström P, Hermelin B and Rusten G (eds), *Services and the Green Economy*, London: Palgrave Macmillan, 99–124. 2016.	Xiangxuan Xu and Patrik Ström	The transformative roles of knowledge-intensive business services in developing green ICT	1) Identify the roles of KIBS in developing green IoT services. 2) Implications on the geography of green IoT service development.	Six green IoT projects in the Gothenburg region	The paper proposes an "ACT" framework to describe the KIBS roles in developing green IoT services. Implications on the geography of green IoT service development are threefold: 1) The importance of the "intangibles"; 2) Region as test-beds for green technology/services; 3) The transformation of service to the multi-actor frameworks interacting with each other on different geographic levels.

Article 3	Published in *Chinese Journal of Urban and Environmental Studies* 5(2). 2017. DOI:10.1142/S2345748117500099	Xiangxuan Xu	The contextual dynamics of Internet of Things applications in smart public bike sharing services	Does place matter for the adoption of ubiquitous IoT technologies?	The smart Public Bike Sharing schemes in Hangzhou China and Gothenburg Sweden	The paper concludes that the contextual factors such as public motives, user preferences, and governance can impact the implementation of smart PBS schemes and the evolution of their service characteristics. A model that explicitly includes these three contextual factors is proposed to analyse the innovation process of public services utilizing IoT.
Article 4	For submission to an international refereed journal	Xiangxuan Xu	Supranational Resource Concertation – The role of public policy for new industrial path creation in the European Union	How does public policy facilitate the non-linear path creation of new technology-based industries on the supranational level?	The evolution of Internet of Things policy-making in the EU during the last decade	The study reveals that supranational resource concertation has played an essential role of the EU institutions to unleash the potential of IoT in Europe. Theoretically it contributes to the theory development by proposing an analytical framework on the role of EU policies for path creation. Policy implications contribute to the construction of an evolutionary alternative for public policy to adapt to the non-linear path of embryonic industries.

ADDITIONAL RELATED PUBLICATIONS

Article No.	Title	Relation to the articles	Author(s)	Type of the publication	Book/Journal	Key research questions
Article 5	Interactions between Sweden and the EU before and after the Digital Agenda	Reference to Article 4	Xiangxuan Xu	Book Chapter	In Linda Berg and Rutger Lindahl (eds), *Förhoppningar och farhågor - Sveriges första 20 år i EU*, Gothenburg: Centre for European Research, University of Gothenburg, 217–232. 2014.	Does Sweden as a norm-setter, assert a soft leadership in ICT policy-making in the EU?
Article 6	Crossing the Digital Desert in Sub-Saharan Africa: Does Policy Matter?	Reference to Article 3	Robert Wentrup Xiangxuan Xu, H. Richard Nakamura, Patrik Ström	Journal Article	*Policy & Internet* 8(3): 248-269. 2016.	What policy instruments have impacts on the Internet penetration in Sub-Saharan Africa?

LIST OF ACRONYMS

6LoWPAN: IPv6 over Low Power Wireless Personal Area Networks
ACT: Adhesive, Canal and Telescope - a framework to describe the KIBS roles for developing green ICTs
AWS: Amazon Web Services
CAICT: China Academy of Telecommunication Research of MIIT
CASAGRAS: Global RFID-Related Activities and Standardization
CoAP: Constrained Application Protocol
CRA: Constructing Regional Advantages
DPWS: Devices Profile for Web Services
EEG: Evolutionary Economic Geography
ERP: Enterprise resource planning
EPC: Electronic Product Code
FDI: Foreign direct investment
FP7: EU Seventh Framework Program for Research and Development
FTC: Federal Trade Commission, US.
GIN: Global Innovation Networks
G-IoT: Green Internet of Things
GPN: Global Production Networks
GPT: General-purpose Technologies
GVC: Global Value Chains
HTTP: Hypertext Transfer Protocol
ICNRG: Information-Centric Networking Research Group
ICT: Information and Communication Technologies
IEEE: Institute of Electrical and Electronics Engineers
IEEE 802.15.4: A technical standard which defines the operation of low-rate wireless personal area networks (LR-WPANs).
IETF: Internet Engineering Task Force
IIoT: Industrial Internet of Things
IoT: Internet of Thing
IoT-A: Internet of Things Architecture
IP: Internet Protocol
IPSO: IP for Smart Objects
IERC: European Research Cluster on the Internet of Things
IT/OT: Information/Operational technology convergence
ITU: International Telecommunication Union
ITU-T: The ITU Telecommunication Standardization Sector
KIBS: Knowledge-Intensive Business Services
LPWA: Low Power Wide Area
LPWAN: Low Power Wide Area Network
MDM: Master Data Management
M2M: Machine to Machine
MIIT: Ministry of Industry and Information Technology, China
momPaaS: Message-Oriented Middleware Services
MQTT: An ISO standard (ISO/IEC PRF 20922) publish-subscribe-based "lightweight" messaging protocol for use on top of the TCP/IP protocol
NFC: Near Field Communications
OASIS: The Organization for the Advancement of Structured Information Standards
OECD: The Organisation for Economic Co-operation and Development
OEM: Original Equipment Manufacturer
PBS: Public Bike Sharing
R&D: Research and development
RIS: Regional Innovation System
RFID: Radio-frequency identification
RPL: IPv6 Routing Protocol for Low power and Lossy Networks
SSN: Semantic Sensor Network
TCP/IP: Transmission Control Protocol/Internet Protocol
TMT: Technology, Media and Telecommunications
uID: Unique/ Ubiquitous Identifier
W3C: World Wide Web Consortium
WISP: Wireless Identification and Sensing Platforms
WSAN: Wireless Sensor and Actuator Networks
WSIS: World Summit on the Information Society
WSN: Wireless Sensor Networks

CHAPTER 1: INTRODUCTION

1.1 THE RESEARCH FIELD

This dissertation is a study of the timely topic - the Internet of Things (IoT), which focuses on the impacts of the new IoT technologies on economic-geographic research. Because IoT is so recent, very few studies have investigated its applications in different societal contexts at various geographic levels. It even seems that this study may be the first attempt to scrutinise the IoT phenomenon from an economic geography perspective. For that reason, there seems to be an urgent research gap that needs to be filled and a large number of the current applications and possible prospects to investigate before one can formulate a more coherent economic-geographic theory for the IoT. A helpful starting point is to place the IoT topic within the larger framework of general information and communication technologies (ICTs) and knowledge with the concept of "context" as a key important entry.

Sociologists and geographers have raised the importance of context when trying to understand the changing spatial patterns of organised social-economic activities that are driven by new ICTs (Castells, 1996; Cooke, 2017; Hepworth, 1986; Inkinen, 2012; Jansson, 2008; Kellerman, 1989; Leamer and Storper, 2001; Malecki and Moriset, 2008; Martin, 2002; Storper, 2009; Tranos, 2013; Wilson et al., 2013). Context in terms of a broad definition sets the circumstances where the proceedings of social-economic actions can be fully understood. Contexts form the complex spatial networks that often are a mix of different levels of geographical scales. As Storper (2009:14) suggests: "There is rarely a clean division between locationally fragmented, highly organised, specialised contexts and highly diverse, market-oriented, dense communication contexts but, rather, some fascinating mixes of them." Three strands of the literature stress such spatial patterns from different perspectives.

First, the general economic geography, especially the knowledge economy literature, has paid considerable attention to the **local/regional-global dimension**, which describes the contemporary economic space as locally concentrated specialisation and the globally fragmenting and relocating of production and services (Bathelt et al., 2004; Coe et al., 2004; Dicken, 2015; Morgan, 2004; Storper, 2009). The advancement of ICTs further contributes to reinforcing the geographic configuration of economic actions by task (context-based) rather than function (structure-based) (Grossman and Rossi-Hansberg, 2008). As a result, we are witnessing regional specialisation in a growing complicated global production network, which in turn changes the spatial pattern of knowledge diffusion (Coe et al., 2004; Ernst and Kim, 2002).

Secondly, the information society literature emphasises the **digital/cyber - physical space dimension**, which defines the spatial consequences of ICTs as a stretching and distortion of the economic space using the dual logic of concentration and dispersion. Such a dual logic causes both a convergence and a divergence of individuals, communities and regions (Castells, 2004, 2010; Dodge and Kitchin, 2001; Kellerman, 2002, 2016; Malecki and Moriset, 2008; Webster, 2014). This is social progress that Castells (1996) identifies as the "informational mode of development" where information becomes the source and the product of the economy. This mode is supported by both convergent and integrated pervasive technology systems, provides growing flexibilities in societal structures, and drives the networking logic for organizing social-economic relationships (Inkinen, 2003).

Third, the Knowledge-Intensive Business Service (KIBS) literature applies a **multilevel dimension** that draws attention to the intermediary roles that KIBS functions play to facilitate interactive learning across the territory and knowledge domains, as well as across industrial and sectoral boundaries (Bryson and Daniels, 2007; Coombs and Miles, 2000; Den Hertog, 2000; Muller and Doloreux, 2009; Muller and Zenker, 2001; Strambach, 2008). This literature also suggests that economic and innovation activities are inherently service-informed (Wood, 2005), or even service dominant (Lusch and Vargo, 2006; Vargo and Lusch, 2008). KIBS activities are thus crucial to knowledge production and the transfer of innovation networks in various geographical configurations. Based on this specific techno-economic and institutional structure, regions can become seedbeds or incubators for the foundation of KIBS (Koch and Stahlecker, 2006; Wood, 2005). In recent years, there has been an increasing interdependency between KIBS activities and manufacturing, such as the co-agglomeration of producer services and manufacturing (Jacobs et al., 2014; Ke et al., 2014), and the servitisation of manufacturing (Chesbrough and Spohrer, 2006; Coffey, 2000; Jacobs et al., 2014; Ke et al., 2014; Moulaert and Gallouj, 1993; Ström and Wahlqvist, 2010).

A synthesis of these three strands of literature suggests that the rapid development and adoption of ICTs, such as computers, mobile telephony and the Internet hitherto has not affirmed the "end of geography" hypothesis (Alvstam et al., 2016:48; Cairncross, 2001). Rather, contemporary economic space has become increasingly complex. Both the local-global and digital-physical dimensions can affect spatial consequences, and this process is further complicated by the KIBS activities that facilitate interactive learning for a multilevel configuration of knowledge and innovation networks. However, the economic space is not randomly organised. Such complexity can be understood within a common theme: that is, a "**context-based**" concept. Therefore, the geography of context serves as a critical and analytical proxy to examine fully the relationship between the development of ICTs and the changing geography of manufacturing and services in a knowledge-based information society.

Although the geography of context is used explicitly or implicitly to discuss the spatial patterns of modern economic space, a theory of "context" is under developed (Storper, 2009). Gertler (2003) theorised the economic geography of context by revealing the reflexive relationship between tacit knowledge and context. Storper (2009) developed the theory of "context" to conceptualise the dynamic relationship of regional specialisation to the globalisation process (Coe et al., 2004). Both theories contribute to analysing and understanding the local-global spatial dynamics of knowledge production, innovation networks, and trade. In recent years, the emergence of the new paradigm in ICT development, the IoT, is expected to affect the spatial dynamics of knowledge production through a still further convergence between the digital and the physical world. This dissertation, therefore, attempts to advance the understanding of the spatial characteristics and the consequences of this technological change by integrating the above three perspectives: the digital-physical dimension, the local-global dimension, and various factors from multilevel contexts that affect the applications and prospects of the IoT in society. It thus contributes to the development of an economic-geographic approach to understand certain emerging IoT issues.

1.2 PROBLEMATISATION

Here is the transition to examine further. Since the late 2000s, the Internet is no longer a global network of billions of connected computers and mobile phones, but rather a growing network of hundreds of billions of intelligent devices and systems for the smart home, smart city, smart industry and connected car applications, to name just a few. Due to the advancement of network sensor technologies, cloud computing, and artificial intelligence, an increasing number of connected devices and systems are now embedded with the cognitive abilities to feel and communicate with their contextual environment, which then lead to machine learning[1], remote control, and autonomous machines and systems, known as artificial intelligent systems (OECD, 2015:239).

This transition changes how social-economic space is constructed. The ongoing transition from the Internet age to the Internet of Things age is a paradigm shift of knowledge production and interactions; information and knowledge can be produced and disseminated either without or with very little human interventions. Non-human actors are given cognitive abilities, thus joining with humans to become the producers and carriers of knowledge, especially tacit knowledge. Since the Internet is often considered as the "information highway" that changes the speed of information transfer, this feature differentiates the IoT from the Internet overall.

On the other hand, the intertwining of the physical and the digital space is inseparable. This characteristic differentiates the IoT from other types of automotive machines systems that can function without any plug-in to the digital world. Therefore, the change is not only a technological one, but also a social and economic shift that has the potential to transform how we work and live for decades to come. In its essence, the IoT age represents an undergoing phenomenon where economic and everyday activities are operating in a constant intertwining of the physical and the digital worlds for either geographically dispersed or concentrated smart devices/systems that are geographically mobile or fixed. This qualitative change calls for re-conceptualising the social-economic space that integrates these local-global and digital-physical dimensions.

As a social-economic phenomenon, this grand convergence of atoms and bits opens new opportunities for developing new types of digital services (i.e., a smart home, smart city and smart transportation) and the servitisation of agriculture and manufacturing (i.e., smart farming and Industry 4.0), pushing forward a further blurring of manufacturing and service. At the same time, the convergence of the physical and the digital worlds could lead to disruptions in the governance issues of interoperability, standardisation, data security and the protection of privacy. As a result, the promise and pitfalls of the IoT technologies will challenge policymakers worldwide. These issues are debated mainly from a technological development perspective by computer scientists, engineers, and lawmakers. So far little attention has been paid to the context wherein these technologies are developed and adopted. This dissertation, however, applies the

[1] Machine learning is giving computers the ability to learn without being explicitly programmed, e.g., AlphaGo acquiring the skills to play the board game GO.

geographical perspective of context and argues that without an understanding of the spatial characteristics of these IoT issues, the business circle and our society cannot fully benefit from the uptake in IoT technologies.

The spatial characteristics of IoT seem contradictory. On the one hand, IoT is a type of space-shrinking technology that reduces the spatial constraints of social economic activities. On the other hand, the production and adoption of IoT technologies are influenced by institutional, social, organisational, and cognitive factors that are spatially constrained.

This contradiction is due to the reflexive relationship that exists between the IoT and its context. Due to IoT's profound influence on knowledge production and interaction, it affects the geography of context. Meanwhile, like other types of ICTs, the development and adoption of IoT technologies are influenced by the institutional, organisational, and cognitive contexts. This relationship between IoT and context can be discussed by examining two research themes: (1) how does the adoption of IoT technologies impact context? And (2) how does context affect the production and adoption of the IoT technologies? Answering these two questions can help clarify several critical aspects of IoT in terms of value creation, technology development and adoption, its spatial consequences for industry dynamics, and policy implications. The first theme explores the way IoT redefines distance, the division of labour, knowledge production and interactions, which can shed lights on the mechanisms of IoT enabling innovation in productions and services. The second theme can help to illustrate the complexities of the social constructs when developing and adopting IoT technologies.

With respect to the IoT and its context, the distance is not linear, and space is theorised as being relational and context-based.

1.3 AIMS AND RESEARCH QUESTIONS

The primary task of the dissertation project is to explore the spatial characteristics in the emerging IoT issues. It contributes to theorising the geography of context by integrating three spatial dimensions of knowledge production and interactions: the local-global dimension, digital-physical dimension and the multilevel knowledge dynamics. An economic-geographic perspective is underdeveloped in the current debate in the international IoT research community. The popular notion of IoT as connecting anything at any time at any place (ITU, 2005) suggests a return to the "end of geography" thesis. It asserts that digitalisation and globalisation significantly reduce the time-space constraints of human activities on earth and thus declare the death of distance.

These spaceless sentiments of IoT are indeed exaggerated and even misleading. A key issue is often the missing or underestimated social and human aspects of IoT (Dutton, 2014). Although the emphasis on things by using the term the "Internet of Things" captures its technological novelty - "without or with less human-intervention", that does not mean that human aspects are irrelevant. On the contrary, the human factor plays a central role, because things are connected for people - to provide them with useful information and services regarding human activities. The production and use of the IoT applications occur within the social environment and are thus influenced by contextual factors. As human activities are always spatially-bounded in their contexts, "context" becomes the key theoretical concept to understand the spatial characteristics during the development of IoT applications and the adoption of IoT services. On the other hand, the adoption of IoT technologies can redefine distance and the spatial relationships of both things and people. Consequently, it redefines the construct of contexts for manufacturing and services. In this sense, an economic-geographical perspective entails the necessity of having a human-centred approach to the adoption of IoT.

As discussed in Section 1.2, this dissertation focuses on exploring the relationship between the IoT and context using two themes. Five research questions are posed that relate to these two themes:

Theme 1: How does the adoption of IoT redefine context? (IoT to context)

> *RQ1: How does IoT redefine knowledge production/interaction and enable innovation?*
> *RQ2: What are the spatial characteristics and consequences of adopting IoT?*

Theme 2: How does context affect the production and adoption of IoT? (Context to IoT)

> *RQ3: In what way does place matter for the production of IoT applications?*
> *RQ4: In what way does place matter for the adoption of IoT services?*
> *RQ5: How do public polices facilitate the emergence of the IoT industry?*

1.4 STRUCTURE OF THE THESIS

This thesis is a compilation of four core research papers and an overarching introduction, i.e. a "kappa", to integrate and link all articles together. The "kappa" provides a synthesis of the dissertation project and is organised into five chapters. Chapter 1 offers a research overview and the author's contribution to the research field. It contains the overall aim and research questions of the dissertation and a summary of individual articles, including how they are interrelated. The emergence of the IoT industry explained in Chapter 2 proves a brief introduction of the IoT industry, including the evolution of its definition and its underlying political and industry drivers. The theoretical background presented in Chapter 3 provides a review of the related literature that sets forth the theoretical landscape of the research project. Chapter 4 presents the ontological, epistemological positions of the research and its methodological considerations, and critically reflects on the choice of cases and the data collection. The concluding Chapter 5 synthesises the main findings and their limitations, offers implications for individuals, companies and policymakers that are based on the overall theme of the thesis, then clarifies the author's contributions and suggests topics for future research.

Four articles were developed from 2012 to 2017. They are organised here in successive order so as to illustrate the emergence of the IoT industry from a technological creative vision to reality (see Figure 1). This sequence also reveals the author's learning process over time.

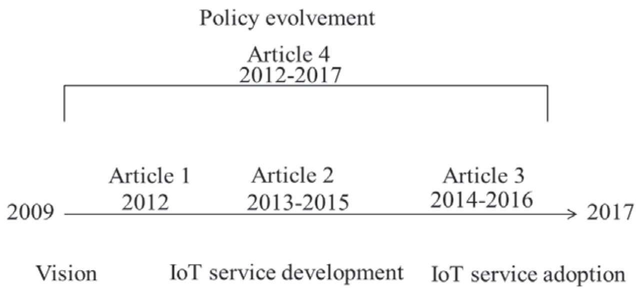

Figure 1: The successive order of the articles (Source: Author)

During the time when Article 1 was developed, IoT was more of a nascent vision than an actual reality, so this paper focused on defining the IoT in a service and innovation context. The case of the Chinese IoT pilot city, Wuxi, was presented to reflect the interactions between industry and policy evolvement that served to facilitate this new industry formation. Data were collected from the major actors from both public and private organisations for building this pilot city. The unit of analysis was *place*, namely, the IoT pilot city Wuxi. Article 2 and Article 3 further discuss the spatial factors involved in developing and adopting IoT technologies. During the first decade or the 2010s, the IoT industry emerged from a technological vision to early market adoption. Article 2 looks at the technology development phase and scrutinises six ongoing IoT projects in the Gothenburg region, including the applications for both business-to-business and business-to-consumer users. Data were collected from the actors in this region. The unit of analysis was *project*. Article 3 turns to the adoption of the IoT technologies and examines the most widespread IoT service – the smart Public Bike Sharing (PBS) schemes. It is a public service case study, and its data were collected from the major actors involved in implementing the PBS projects in the hosting cities. The unit of analysis again was *project*. Article 4 discusses the role of public policies in facilitating the uptake of IoT. It follows the evolution of the European Union (EU) IoT policy-making over the last decade (2005-2017). Data were collected from both policymakers and civil servants. The unit of the analysis was *policy*.

Figure 2 summarises the structure of the four articles and shows the relative position of each article compared to the others by sector, level of analysis, and unit of analysis. A local-global perspective defines the level of analysis wherein micro refers to local (e.g., within a city), and macro references the global (e.g., outside the national boundary).

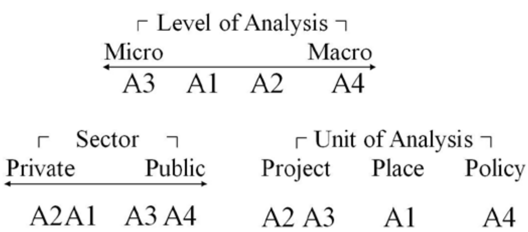

Figure 2: The structure of the independent articles in the dissertation by sector, level of analysis, and unit of analysis (Source: Author)

The table below summarises the linkages of each article discussed here to the research questions, the level and unit of analysis, and the respective research themes. Since IoT technologies have so far not achieved mass adoption, the discussion of Theme 1 is largely one related to theory and future outlook. Therefore, regarding RQ1 and RQ2, the "kappa" is also used to complement the articles.

Table 1: Overview of the articles studied (Source: Author)

Articles	**Research Questions**	**Research Theme**
1	RQ1, RQ2, RQ5	IoT to context; context to IoT
2	RQ3	context to IoT
3	RQ4	context to IoT
4	RQ5	context to IoT
Kappa Chp.3	RQ1, RQ2	IoT to context
Kappa Chp.5	RQ2	IoT to context

Following the structure of the thesis, the next subsection provides an overview of the four articles noted thus far.

1.5 OVERVIEW OF THE ARTICLES

Article 1 (Single authored paper) Internet of Things in Service Innovation, published (2012) in *The Amfiteatru Economic Journal* 14(6): 698–720. This paper defines the IoT in the service innovation context. It discusses such questions as *why and how IoT enables innovations in service offerings. And, during the early emergence phase, how did the government respond to this rising phenomenon?* The paper combined the theories from the information sequence, ICT, and the changing geography of services with the economics and creativity of networks. The author built an "information sequence loop" to situate the IoT into the service innovation sphere. The paper pointed out that the key value of connecting objects and people is to turn data into useful information and valued services. Innovation in services was enabled by automation and telematics. The development and adoption of IoT services were place-rooted in complex local and global agents' frameworks. The value creation of IoT services relates to when, where, what, how and for whom the service is performed. Moreover, for those services that concern critical social infrastructures, the roles of the regulators, governments, and authorities are crucial. The current obstacles to IoT services imply that the development patterns can be varied at different places and in business segments.

The case of the first IoT pilot city, Wuxi, in China suggested a strong government-led initiative. It was combined with the national will to challenge the US superiority during the Internet era, and the local anxiety toward tackling structural change and industrial upgrading. The realisation of this ambition was supported not only by the first mover advantage, but also by the city's geographical proximity to the node city, Shanghai, and the knowledge base of software development and information technology service. The author raised questions about the government's push model and suggested that it was not sustainable. The government initiative must be followed by a value chain and business model development from the industry.

Article 2 (Co-authored with Patrik Ström) The Transformative Roles of Knowledge-intensive Business Services in Developing Green ICT, published in Jones A, Ström P, Hermelin B and Rusten G (eds), *Services and the Green Economy*, London: Palgrave Macmillan, 99–124. 2016. After a general discussion on the geography of IoT in services, this paper shifts the aspect to the development of IoT services. The underlying research question is *in which way does place matter for the development of the IoT applications?* Since IoT technologies are widely accepted as a major driver for sustainability, six Green IoT (G-IoT) projects in the Gothenburg region were selected and analysed. These cases reveal that place matters for the development of IoT applications ("region as a test bed") and the value creation of the IoT services. These aspects are coupled with the intermediate role of KIBS in the co-creation of a greening process.

The cases raise the importance of the "intangibles," although rather tacit and invisible, but crucial for the successful realisation of G-IoT projects. During the non-linear path of developing G-IoTs, the "intangibles" (such as trust, cross-boundary tacit knowledge sharing, and the willingness to seek new opportunities even among competitors) are embedded in the interactivities of business social relationships and thus play an essential role. The cases also indicate how value is created for the IoT applications. The value does not come from the physical devices of wires, sensors, screens, and chips, but rather relies on how many users or other devices are connected to it and, more importantly, the interactions between them.

The article demonstrates the knowledge, competence, and trust accumulated in telecom and transportation by the nexus of KIBS growing around the Multinational Corporations in the Gothenburg Region laid the foundation for that region to become a test bed for green transport/vehicles services. The knowledge is found in the state of constant upgrading and changing from either inside the region or outside the region. In this respect, KIBS are at the core of the activities' taking place on a multilevel geographical scale, where local presence and international reach through contacts and clients are essential for knowledge transfer. Knowledge and policy networks are complex, and they take a long time to develop. This process creates a regional competitive advantage that can be sustained over time and make it more difficult for actors to leave for other locations.

Article 3 (Single authored paper) The Contextual Dynamics of the Internet of Things Applications in Smart Public Bike Sharing Services, published in the *Chinese Journal of Urban and Environmental Studies* 5(2). 2017. This article followed the emergence phase of the IoT industry and investigated its implementation. Since the technical characteristics of IoT are rather identical around the globe, the aim here was to ask *if place still matters for their adoptions.* By early 2014, the most widely spread IoT service was the smart PBS schemes. Prior studies of smart PBS schemes find positive effects for the host city's image and sustainable mobility. Less attention was paid to the impact of the host city's context on the evolution of their service characteristics. This paper proposes a model that explicitly includes the contextual dynamics for public service innovations that can utilise IoT. The model is used to discuss two empirical cases from Sweden and China. These results reveal that public motives, user preferences, and governance can impact the evolution of service characteristics of smart PBS schemes, a factor that is important for smart PBS planners, operators, and policymakers to consider. The best PBS scheme is one that adapts to the characteristics of the host city and the changing needs of the users. Moreover, this study reflects new complexities that were arising for digital public services, such as the protection of data and privacy.

Article 4 (Single authored paper) Supranational Resource Concertation – The role of public policy for new industrial path creation in the European Union, (for submission to an international refereed journal). This article turns to the policy side. The core research question here is: *How does public policy facilitate the emergence of the new technology-based IoT industry at the EU level?* It addresses the evolution of the IoT policy-making in the EU during the last decade as the case. The paper concludes that supranational resource concertation describes the key role for EU institutions to take to facilitate the path creation of the IoT industry. It contributes to the theory development of path creation by inserting a supranational EU dimension. By applying a resource-based view of path creation, this paper defines the EU dimension as one that facilitates the creation and movement of key resources by actors at international, national, and sub-national levels. Based on the EU policy-making process, the author developed an analytical framework to use to discuss the role of EU policies for facilitating the emergence of new technological-based industries. Using the case study approach, the author further identified a chord of policy actions to support supranational resource concertation during the different policy-making phases.

Since the path-creation process is a nonlinear one, the policy implications contribute to the construction of an evolutionary alternative for policy-makers to use to tackle this challenge. The case study implicitly confirms the adoption of concepts, such as “related variety” and “Constructing Regional Advantages.” The key observation from this IoT case is that when responding to the nonlinear emergence of the IoT industry, the policy-making process at the EU level is also nonlinear. It is a learning and adaptation process. The policy implications of this observation are twofold. First, policy-makers shall act proactively not based on prediction, but rather on the emerging future direction of the industry. This process is based on consensus building among the key stakeholders in the technological field. Secondly, the future trends and visions of this emerging industry are evolving. Thus, new mechanisms will be built to support policy-making as a dynamic resource concertation process. The Commission’s policy entrepreneurship, which is supported and complemented by the supranational clusters, is an example of how to achieve a dynamic balance of all the various interests.

Overall, these research articles provide insights to understand the spatial characteristics and consequences of adopting IoT technologies. They discuss the relationship between IoT and context in various aspects that are related to the research questions. The adoption of IoT technologies can redefine context through automation and telematics. Automation and telematics change the conceptualisation of distance, the division of labour, knowledge creation and interactions, which enables innovation in productions and services. Various contexts such as the institutional and historical characters of a place, people and social-economic relationships profoundly affect the development and adoption of IoT technologies. Thus, the deployment of IoT technologies is place-rooted in complex local and global agents’ frameworks. Regions and places can be test-beds for developing IoT applications because knowledge and policy networks take a long time to develop, which can be sustained over time. The value creation of IoT deployment does not come from the physical devices, but rather relies on the networks of the users and the connected devices, and their interactions.

CHAPTER 2: UNDERSTANDING THE INTERNET OF THINGS

The term IoT has been used in multiple ways in business and everyday life. Some are narrower, like the everyday connected wearable and kitchen appliance; some are broader, such as Industry 4.0 and the smart city; some are innocuous, like the smart door locks and smart bikes; some are controversial, such as the experimental chip implant in humans and the self-driving car. Like it or not, the rise of the IoT is transforming how we work and live and will continue to do so for decades to come. In its essence, the term represents an ongoing phenomenon where economic and everyday activities are operating in a constant intertwining of the physical and the digital world.

So far, the rise of IoT has been a technology-industry driven phenomenon and supported by various policy initiatives in the major economies in the world. This chapter begins with a review of the IoT vision and its technologic roots to come to a definition. Based on a close review, four common misunderstandings of the IoT concept are laid out here and a short history of the IoT emergence is offered, focusing on both its industry and its policy drivers.

2.1 ONE PARADIGM SHIFT, MANY TECHNOLOGIES

IoT is not an entirely new idea, but its scale, application and sophistication make this emerging phenomenon a genuine new paradigm (Dutton, 2014; OECD, 2015). During human history, tools, machines, electricity, computers and the Internet one after another have changed the manner of living and productions, and transformed the relationship between humans and non-humans. Numerous thinkers and technologists have envisioned a future world where connectivity is everywhere for anyone about anything (ITU, 2005:2). Among these, the most famous example would be Nikola Tesla who was a Serbian-American physicist and inventor who contributed to the development of modern alternating current electrical system (Atzori et al., 2017; Hunt and Draper, 1964:177):

> *"When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being partides of a real and rhythmic whole. We shall be able to communiate with one another instantly; irrespective of distance…the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. A man will be able to carry one in his vest pocket."*

It is not entirely confirmed that Tesla said these words over a century ago. The popularity of this myth, however, shows the far reaching impact of technological vision on everyday reality. Some more recent examples come from the dawn of the Internet age. In 1993, David Gelernter, a Professor of Computer Science at Yale University predicted the convergence of the real and digital worlds. In his book, *Mirror the Worlds*, he said (Gelernter, 1993:1):

> *"You will look into a computer screen and see reality…Some part of your world—the town you live in, the company you work for, your school system, the city hospital—will hang there in a sharp colour image, abstract but recognisable, moving subtly in a thousand places."*

Mark Weiser was a chief scientist at Xerox PARC (Palo Alto Research Center Incorporated). Some may even consider him the father of Ubiquitous Computing. In a well-cited article entitled *The Computer for the 21st Century,* he defined *Ubiquitous Computing* (Weiser, 1991) as noted below, and it was used as the philosophical inspiration to define IoT in the 2005 International Telecommunication Union (ITU) Report.

> *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it… Such a disappearance is a fundamental consequence not of technology, but of human psychology. Whenever people learn something sufficiently well, they cease to be aware of it".*

A widely recognised concept that is characteristic to IoT is called "SPIME". The term was invented by the cyberpunk founder Bruce Sterling, and it means *"the protagonist of a documented process… an historical entity with an accessible, precise trajectory through space and time"* (Sterling, 2005:77).

Except for SPIME, IoT has many cousins in different technological domains, including the Physical Internet, Ambient Intelligence, Machine to Machine (M2M), Web of Things (WoT), Connected Environments, Wireless Sensor Networks (WSN), Wireless Identification and Sensing Platforms (WISP), Situated Computing, and Future Internet, to name just a few. The exact term, the "Internet of Things", was coined by the British technologist, Kevin Ashton, in 1999, at the presentation of a Radio-frequency identification (RFID) project for supply chain management innovation at the Massachusetts Institute of Technology (MIT) Auto-ID Lab. The basic idea is that RFID and sensor technology would *"enable computers to observe, identify and understand the world without the limitations of human-entered data"* (Ashton, 2009). Although today, the term is used in a much broader way, Ashton's original reference to the IoT was inherently an RFID application.

IoT is not a single technology, but an umbrella of technologies that have integrated and will continue to evolve with the ongoing advent of new enabling technologies. Atzori et al. (2017) proposed to understand the evolution of IoT technologies in three generations (Table 2). They identified 11 key IoT technological fields that have contributed to the emergence of IoT and to its development over the years. They introduced major objectives in each addressed technological fields with their key enabling standards. The transition between generations is not only characterised by the introduction of new technologies, architectures and standards, but also is motivated by different ways to approach the IoT vision. The first generation - the tagged things envisions the integration at the object/system layers to build inter-connected networks for physical things. The second generation focuses on giving the "things" the capabilities to be directly connected to the Internet via smart gateways. The third generation is the age of social objects, cloud computing and future Internet, and according to Atzori et al. (2017:132), it will be "people-, content-, and service-centric".

Table 2: The IoT generations, major objective for each addressed technological field and key standards (Source: Atzori et al., 2017)

Generation	Technological fields	Major objectives	Relevant standards
I: The tagged things	Tagged objects	To uniquely identify objects through appropriate naming and architecture for the retrieval of objects' associated information	EPCglobal
	Machine-to-Machine (M2M)	To define a reference architecture for machine-to-machine communications	One, M2M, ITU-T FS M2M
	Integration RFID with WSN	To seamless combine data coming from RFID tags with data generated by sensors connected through WSNs	Missing
II: Full interconnection of Things and the (social) Web of Things	Internetworking	To allow constrained devices to adopt the TCP/IP protocols for a seamless integration in the Internet	IETF 6LoWPAN, ROLL RPL, IEEE 802.15.4
	Web of Things	To allow constrained devices to take part to web communications	IETF CoAP, OASIS DPWS
	Social network services	To allow people to share data generated by their smart objects with people they know and trust, leveraging the existing human social networks services	Missing
III: Age of social objects, cloud computing, and future Internet	Social Internet of Things	To make objects able to participate in communities of objects, to create groups of interest, and to take collaborative actions with the objective to facilitate service and information discovery	Missing
	Semantic	To describe the features of the IoT objects to foster systems interoperability	W3C SSN
	Future Internet	To introduce the Information Centric Networking feature into the IoT world so as to introduce content centric-driven rather than host-driven communications	IETF ICNRG
	Cloud	To empower objects with storage, communications and processing capabilities coming from the cloud	Missing
	Evolved RFID-IoT integration	To facilitate the integration of the RFIDs into the IoT applications	Missing

Gartner, the technology consulting firm, used a broader commercial lens to illustrate the various technologies associated with the IoT vision. In the most recent Hype Cycle for IoT, more than 30 critical technology building blocks were included in the S shape diffusion curve[2]. The 2015, 2016 and 2017 lists are combined in Table 3.

[2] The Gartner Hype Cycle is a model designed to help firms assess the building blocks and the levels of risk, maturity, and hype associated with a transformative trend. All technologies listed are connected with the IoT trend. Its method can be found at: http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp (retrieved by 27 July 2017).

Table 3: Gartner Hype Cycle for IoT (Source: Gartner, 2015-2017)

Phases	2015	2016	2017
On the Rise	IoT Authentication Digital Security Licensing and Entitlement Management Energy Harvesting IoT-Enabled ERP IoT Business Solutions Things as Customers Wearable User Interface in Logistics Operational Intelligence Platforms Connected Home IoT Platform Real-Time Analytics	Licensing and Entitlement Management Digital Twin IoT Authentication Infonomics Things as Customers IoT Business Solutions Digital Ethics Edge Analytics IoT-Enabled ERP IoT Platform IoT Services	Licensing and Entitlement Management IoT-Enabled Product as a Service Infonomics Hardware Security Digital Twin Managed IoT Services IoT Business Solutions IoT Edge Analytics Digital Ethics IoT-Enabled ERP
At the Peak	Embedded Software and Systems Security Wide-Area IoT Networks Event Stream Processing IoT Architecture Quantified Self IT/OT Integration iBeacons and Blue tooth Beacons Predictive Analytics Smart Transportation Wearables Low-Cost Development Boards Home Energy Management/Consumer Energy Management IT/OT Alignment	IoT Edge Architecture IoT for Customer Service Connected Home IoT Architecture IT/OT Convergence and Alignment Wide-Area IoT Networks Embedded Software and Systems Security Event Stream Processing Machine Learning Enterprise Information Management Programs Predictive Analytics Low-Cost Development Boards IT/OT Integration	IoT Security IoT Platform IoT Services IoT Edge Architecture Machine Learning Autonomous Vehicles Event Stream Processing Connected Car Platforms Low Power Wide Area (LPWA) Enterprise Information Management Programs
Sliding Into the Trough	Automobile IP Nodes Cloud MOM Services Personal Health Management Tools Operational Technology Platform Convergence Operational Technology Security Big Data High-Performance Message Infrastructure Managed Machine-to-Machine Communication Services	Message Queue Telemetry Transport IoT Integration Asset Performance Management Cloud MOM Services Managed Machine-to-Machine Communication Services Operational Technology Platform Convergence Smart Lighting	Low-Cost Development Boards Intelligent Building Automation Systems IoT Integration IT/OT Alignment Managed Machine-to-Machine Services Asset Performance Management Smart Lighting
Climbing the Slope	Enterprise Manufacturing Intelligence	MDM of Product Data Data Federation/ Virtualization Tools	Cloud MOM Services (momPaaS) Message Queue Telemetry Transport MDM of Product Data

Atzori's et al. (2017) summary is based on the technological fields that are related to the realisation of the IoT vision. While the Gartner Hype Cycle appears in the later phase, i.e. the commercisation of IoT. A holistic picture would be the combination of both.

In conclusion, the fragmentation of terms is the result of path dependency in the different technological domains and communities that the IoT vision encompasses. These terms exist under a common techno-social paradigm shift: The convergence of the physical and digital world.

2.2 MANIFOLD DEFINITIONS, ONE CONVERGENCE

Due to the diverse technological domains that are involved in the realisation of the IoT vision, its definition, hitherto, still lacks unity (Atzori et al., 2010; Kramp et al., 2013). Some researchers and institutions argue for a "*lingua franca*" of IoT (Bassi and Lange, 2013). For instance, since 2009, the IoT-A project was funded by the EU Seventh Framework Program for Research and Development (FP7). This project brought together a joint force of researchers from more than 20 large industrial companies and research institutions to search for the common ground of IoT architecture. A more recent project has been the IEEE IoT Initiative, i.e. *Towards a Definition of the Internet of Things (IoT)*. This initiative intended to establish a baseline definition of IoT applications that is applicable to both localised systems and a large global system. The ITU Telecommunication Standardization Sector (ITU-T) is responsible for studying technical, operating and tariff questions. It provided a Recommendation for a worldwide definition to standardise telecommunications (International Telecommunication Union, 2012:1):

> *"A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies."*

OECD offered a broader definition using the digital economy perspective (OECD, 2015:239):

> *"The term implies the connection of most devices and objects over time to a network of networks. It encompasses developments in machine-to-machine communication, the cloud, big data and sensors, actuators and people. This convergence will lead to machine learning, remote control and eventually autonomous machines and systems. "*

Over the project period, at least 60 definitions were collected from international research communities, policy documents, various funding programmes, IoT conferences, exhibitions and company websites. These definitions all stress the meaning of IoT in one or more aspects.

Some definitions apply the beauty of simplicity:

> *"Services + Data + Networks + Sensors = Internet of Things" (Nick Wainwright from HP Labs3).*

[3] Source: http://www.future-internet.eu/fileadmin/documents/budapest_documents/Plenary_session/Tues_FI_Conf_1630_Wainwright.pdf (retrieved by 27 July 2017).

"Virtually every physical thing in this world can also become a computer that is connected to the Internet" (Fleisch, 2010:3)

Some definitions are lengthy with many technological details included. The longest version was defined by European Research Cluster on the Internet of Things (IERC), and contains most of the technological aspects of the IoT concept (Vermesan et al., 2009:10).

"Internet of Things (IoT) is an integrated part of Future Internet including existing and evolving Internet and network developments and could be conceptually defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network. In the IoT, "smart things/objects" are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information "sensed" about the environment, while reacting autonomously to the "real/physical world" events and influencing it by running processes that trigger actions and create services with or without direct human intervention. Services will be able to interact with these "smart things/objects" using standard interfaces that will provide the necessary link via the Internet, to query and change their state and retrieve any information associated with them, taking into account security and privacy issues."

The China Academy of Telecommunication Research of Ministry of Industry and Information Technology (CAICT) also gave an extended definition and added the managerial implications[4].

"The IoT is the extended applications and extension of the communication network and the Internet, which uses sensing technology and embedded intelligence to detect and identify the physical world. It is interconnected through the network transmission, by calculating, processing and knowledge mining to enable information exchange and seamless links between people and things or things to things, so that real-time control, accurate management and scientific decision-making of the physical world can be realised." (Author's translation from Chinese)

Besides, many companies have provided their own interpretations according to their specialisations.

For example, IBM[5] emphasises the role of data:

"The Internet of Things refers to the growing range of connected devices that send data across the Internet."

Google[6] raised the value of interaction visibility:

"One workable view frames IoT as the use of network-connected devices, embedded in the physical environment, to improve some existing process or to enable a new scenario not previously possible. These

[4] Source: http://www.miit.gov.cn/n1146312/n1146909/n1146991/n1648536/c3489477/part/3489478.pdf (retrieved by 27 July 2017).

[5] Source: https://www.ibm.com/internet-of-things/resources/library/what-is-iot/(retrieved by 27 July 2017).

[6] Source: https://cloud.google.com/solutions/iot-overview(retrieved by 27 July 2017).

devices, or things, connect to the network to provide information they gather from the environment through sensors, or to allow other systems to reach out and act on the world through actuators... Each of them can convert valuable information from the real world into digital data that provides increased visibility into how your users interact with your products, services, or applications."

Samsung[7] stresses the concept of ambient experience:

"The Internet of Things (IoT) market is continuously growing as more and more devices are joined. We are now witnessing an unprecedented increase of information, services, devices and people that are dynamically interconnected. The digital interactions are being harmonized into an ambient experience that rewrites the traditional definition of being connected."

GE[8] promotes the concept of Industrial Internet of Things (IIoT), also known as the Industrial Internet.

"IIoT brings together brilliant machines, advanced analytics, and people at work. It's the network of a multitude of devices connected by communications technologies that results in systems that can monitor, collect, exchange, analyze, and deliver valuable new insights like never before. These insights can then help drive smarter, faster business decisions for industrial companies."

A text analysis[9] of 60 definitions shows that the top 10 frequently used words are things, the internet, information, connected, network, the world, physical, devices, communicate and services.

Table 4: Word frequency query result of 60 IoT definitions (Source: Author)

Word	**Length**	**Count**	**Weighted Percentage (%)**	**Similar Words**
things	6	108	6,09	matter, thing, things', object, objects
internet	8	69	3,91	cyberspace
information	11	59	3,31	data
connected	9	62	2,92	associated, connect, connectedness, connecting, connection, connections, connectivity, connects, continuously, joined, linked, linking, links, relation
network	7	45	2,55	networked, networking, networks
world	5	47	2,45	exist, existed, existing, global, human, humans
physical	8	37	2,02	materialize, materials
devices	7	27	1,53	device
communicate	11	26	1,47	communicating, communication, communications
services	8	28	1,44	help, service

7 Source: http://www.samsung.com/global/business-images/insights/2016/IoT-Whitepaper-0.pdf (retrieved by 27 July 2017)

8 Source: https://www.ge.com/digital/blog/everything-you-need-know-about-industrial-internet-things (retrieved by 27 July 2017).

9 Anvivo word frequency query result. To increase the accuracy of the result, I took away the term IoT and Internet of Things, and unified objects with things. I applied synonym method to analyse words with similar meanings.

The result can be used to formulate a general definition of IoT: **things/devices** from the physical **world** are **connected** to the **Internet/network,** where **information** is **communicated** to enable **services**. It reveals the essential elements of the IoT with respect to the physical-digital convergence, as well as the value creation mechanisms (Figure 3).

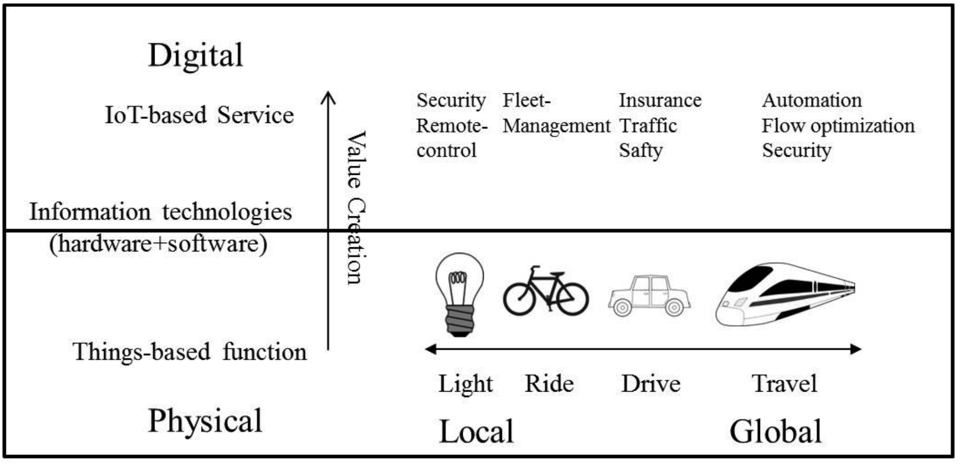

Figure 3: The IoT products-services logic (Source: Author's adaptation based on Fleisch et al., 2014 and Wortmann and Flüchter, 2015)

Figure 3 summarises the key elements and value creation mechanisms of the IoT concept under the convergence between the physical (local-global) things and the digital world. Notwithstanding many definitions of IoT, it is, still, a single convergence.

This dissertation applies this general definition of IoT to develop an economic-geographic theory of IoT. Each independent article in the dissertation adapts this general definition to their empirical conditions. Article 1 developed the definition of IoT in the service innovation context, and highlighted that the value of IoT in the service context is providing useful information and valued services to potential users. Article 2 explored the development of IoT applications in the green ICT field, and stressed the "Green" IoT definition that drives resource efficiency. Article 3 is a case study of the IoT-based fleet management by connecting public sharing bikes, so that it emphasised the local conditions of the host cities that affect technological implementations. Article 4 traced the evolution of the EU IoT policy-making in the last decade. Based on the general definition, it thus underlined the changes of the EU IoT policy frames and venues.

2.3 FOUR COMMON MISUNDERSTANDINGS

Despite the term's popularity in the industry and use by policymakers worldwide, the meaning of the IoT is easily misunderstood.

The first common misunderstanding is the overstress of "Things" and it may lead to the deployment of valueless connected devices. Evidently, when the term was coined by Kevin

Ashton, it was a Things-oriented concept that was enabled by the RFID tags. The United Nations' 2005 Tunis World Summit on the Information Society (WSIS) declared the advent of IoT on the global stage and predicted a new era in which "*today's Internet (of data and people) gives way to tomorrow's Internet of Things*" (International Telecommunication Union, 2005:1). In this report, ITU expanded the technological enablers from RFID tags to a range of wireless sensors and smart things (e.g. SPIME). Nevertheless, the report was stressing many types of "Things" - anything that could be connected to the Internet. The same mistake was made by me during the early phase of this research project. It was appealing to view the rise of the Smart Things as if they respond to the call of Bruno Latour (1993:142) *"we want the meticulous sorting of quasi-objects to become possible -- no longer unofficially and under the table, but officially and in broad daylight."* However, calling anything embedded with chips a Smart Thing is now ignorant and sometimes stupid. Consumers and customers do not buy smart devices, but rather the services that they can benefit from by using the devices (e.g., the product-service logic). Neglecting these aspects may lead to failures of undesired IoT devices.

The second common misunderstanding is to consider the IoT as an extension of the Internet. Since the rise of the Internet 40 years ago, the world has witnessed at least two waves of the Internet revolution. The World Wide Web in the 1990s and the mobile network in 2000s profoundly transformed how we live and work at an unprecedented pace. As the term "Internet of Things" indicates, some may argue that we are now in the third wave of the internet revolution. In fact, many definitions see the IoT as yet another global infrastructure. One driving force underlying this future Internet conceptualisation of the IoT is in the Coordination and Support Action for Global RFID-Related Activities and Standardization (CASAGRAS) consortium[10], and it highlights the importance of including the existing and evolving Internet and network developments in this vision. In this sense, IoT becomes the natural enabling architecture for the deployment of independent federated services and applications, characterised by a high degree of autonomous data capture, event transfer, network connectivity and interoperability (Atzori et al., 2010). Industrial initiatives that are related to this strand are IP for Smart Objects (IPSO), Internet 0 and Web of Things. These actions are based on the next generation Internet Protocol (IPv6) that can provide every connected object with the identifiable and addressable address. Many IoT Infrastructure standards are IP-based. For instance, 6LoWPAN is an adaption layer for IPv6 over IEEE802.15.4 links. It is not wrong but too narrow. The interoperability of the IoT is not only about the infrastructure, but also about relying on transport protocols such as Wi-Fi and LPWAN; data protocols such as MQTT, CoAP and Node; and device management and various semantic protocols. The IoT is not merely a simple extension of the Internet. Neglecting its physical and semantic layers may lead to failures of senseless connectivity.

The third common misunderstanding is to see the IoT as placeless. The "anytime anything at any place" rhetoric underlying the IoT vision often exaggerates its ubiquity or pervasive

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[10] CASAGRAS is a program funded under the European Union's Seventh Framework Programme (FP7). It provides a framework for research to aid the European Commission in navigating international issues related to RFID, in particular the IoT.

characteristics. Indeed, the broad adoption of ubiquitous technologies has transformed the place of the eye and physical senses into networked spaces where people can experience both the material and virtual world. However, these networked spaces are far from being anytime, anywhere, but instead intrinsically emplaced and meaningful - rather than only placeless they offer a more situated and socially constructed sense of place (Willis, 2017). IoT differs from pure digital technologies through its integration of local physical things with the global digital power. The physical things and the people who are using the IoT services are always place-embedded. For instance, it would be hard to believe that the implementation of a smart public transportation project could be successful without a thorough understanding of the main local factors, such as the rules and institutions, the pre-existing relationships in the transportation system, and local commuters' habits and needs. Neglecting the local knowledge and local relationships may lead to failures in local adaptation.

The fourth common misunderstanding is over-emphasising the technological factors. A survey by *The Economist* showed that 95% of executives expected their companies to be using the IoT in three years (Witchalls and Chambers, 2013:5). A sharp contrast was found by a CISCO firm survey in May 2017[11]. It showed the nearly 3/4 of the IoT projects in the US and the U.K. are failing. Human factors, such as culture, organisation, and leadership, indeed are critical. The survey also found that three of the four top factors behind successful IoT projects had to do with people and relationships, such as the collaboration between IT and the business side, a technology-focused culture and IoT expertise. Wortmann and Flüchter (2015) also pointed out several strategic and operational challenges for IoT deployment: 1) Re-define existing business models that may be based on a new positioning of products in the IoT; 2) Re-assess industry boundaries as competition starts to shift and expand; 3) Rigorous hardware and agile software cultures are likely to clash; 4) Modify the after-sales service processes to meet the requirements of connected products; and 5) Connected products enable a more direct communication with customers. Neglecting the human factors when designing, developing and deploying the IoT technologies may also lead to failures in realising the IoT projects fully. These common misunderstandings are summarised in Table 5.

Table 5: Four common misunderstandings of the IoT concept (Source: Author)

Misunderstandings	**May lead to failures**	**Factors to consider**
IoT is about Smart Things	Undesired IoT devices	The product-service logic
IoT is just the extension of the Internet	Senseless connectivity	Systematic IoT service design including the physical and semantic layers
IoT is placeless	Inability to adapt to local conditions	Local factors, preexisting relationships, culture and institutions
IoT is only about technology	Unsuccessful IoT deployment	Human factors such as culture, organisation, geography and relationships

[11] Source: https://newsroom.cisco.com/press-release-content?type=webcontent&articleId=1847422 (retrieved by 28 July 2017).

2.4 INDUSTRY AND POLICY DRIVERS OF THE IOT EMERGENCE

As a type of general-purpose technology[12] (GPT), the IoT represents a paradigm shift with impacts that transcend present industrial and sectoral boundaries. For instance, the "smart manufacturing" includes application areas such as operation optimisation, predictive maintenance, inventory optimisation, health, safety and so on (Manyika et al., 2015). Governments and businesses are expecting the IoT to hit mainstream by 2020 (SAS, 2016). According to Boston Consulting (Crooks, 2017), by 2020, companies will spend an estimated €250bn on the IoT, and by that time, there will be around 7.6bn connected devices operating just in industry. OECD estimated by 2022, an average family of four with two teenagers will have 20 Internet connected devices in and around their home (OECD, 2015:256). As the range of IoT technologies falls within different implementation phases (Table 3), there is a good reason to be sceptical about the 2020 prediction. However, such scepticism cannot defy the fact that the industry is more than ambitious to realise the full IoT vision soon.

It is hard to predict the market potential of IoT. But there are some numbers that offer a big picture. The global market forecast is around $3.9 trillion to $11.1 trillion a year by 2025 (Manyika et al., 2015). A European Commission study estimated that the market value in the EU is expected to reach over €1 trillion in 2020 (Aguzzi et al., 2014). As IoT promises future economic growth and sustainability, it has rapidly evolved from disruptive technologies to national competitive strategies for the major economic entities across the globe (Atzori et al., 2017; OECD, 2015:265).

2.4.1 THE INDUSTRY DRIVERS

In early 2000, IoT was described as a paradigm shift for international trading networks to adopt for use of RFID electronic tags (Ashton, 2009; Schoenberger and Upbin, 2002). Manufacturers and retailers could benefit from the enhanced object visibility such as traceability, status and location. The vision was supported by a range of research laboratories and institutions in the world, e.g., EPCglobal. EPCglobal is an international organisation that promotes worldwide adoption and the standardisation of Electronic Product Code (EPC) technology, including Board members, such as those from Auto-ID Labs, Cisco Systems, DHL/Exel Supply Chain, Haier Group Company, Johnson & Johnson, the US Office of the Secretary of Defense, Procter & Gamble, Sony Corporation and Wal-Mart. Since then, The IoT vision has gone beyond the scope of RFID technologies. A range of technologies and standards that represent different industry alliance and technological domains have been involved and sometimes competed with each other, such as middleware based Unique/ Ubiquitous Identifier (uID) architecture, Near Field Communications (NFC), and Wireless Sensor and Actuator Networks (WSAN) (Atzori et al., 2010). With the advent of manifold technologies that provide universal connectivity and

[12] One of a small number of drastic innovations that creates innovation complementaries that increase productivity in a downstream sector (Helpman, 1998:5; Malecki, 2002:399)

interactions, the IoT vision has evolved to represent and forecast a hyper-connected digital future society.

In 2005 this trend was captured and pushed forward to the global level by ITU. ITU launched a special report about IoT, identifying the key enabling technologies, market opportunities, applications, and challenges. The report has broadened the definition of IoT from disruptive technologies into the future Internet, indeed predicting the advent of the IoT era. It set forth one of the embryonic forms of the global IoT vision as we know it now. Between 2008 and 2009, the number of connected devices exceeded the total world population. The symbolic event was taken up by many impressive forecasts about the exponential growth of the connected devices by the industry, ranging from dozens of billions to 1 trillion[13] by 2020. They may today be judged as having been too high, but at the time these numbers clearly set high expectations of the IoT to take up. Multinational firms across the technology industries, e.g., IBM, Ericsson, Cisco, Intel, Ericsson, Google, and SAP, were early promoters of turning IoT technologies into businesses. Start-up companies were jumping into this "next big thing." In 2008, the first international IoT conference was held in Zurich, and in September, a new global industrial IoT alliance IPSO was formed.

Between 2014 and 2015, IoT has evolved from a technological vision to a reality. A German IoT firm database indicates that by March 2015, there were over 50 Industry consortiums, and at least 317 Multinational Corporations (MNCs), 460 Small and Medium-Sized (SMEs) companies and over 1000 Start-ups running IoT projects (IoT Analytics, 2015). These numbers could even be under-estimated due to language barriers and information unavailability for a large number of start-up projects. Another indicator is the number of IoT merger and acquisitions (M&A). According to Ovum (Rakity et al., 2017:7), the total value of acquisitions by technology, media, and telecoms (TMT) companies into IoT-related firms was over \$126bn. In 2015, the total disclosed IoT acquisition value was \$25bn, and in 2016 the number had quadrupled to \$93.3bn. Some signature deals included Google's \$3.2bn acquisition of Nest (2014), Samsung's \$200M deal with SmartThings (2014), Qualcomm's \$47bn purchase of NXP Semiconductors (2016), Softbank's \$31bn ARM acquisition (2016) and Cisco's \$1.4bn acquisition of platform provider Jasper Wireless (2016). Figure 4 documents some of the star M&A deals with their different strategies from 2011to 2017.

[13] Source: http://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-of-things-forecast-of-50-billion-devices-by-2020-is-outdated (retrieved by 29 July 2017).

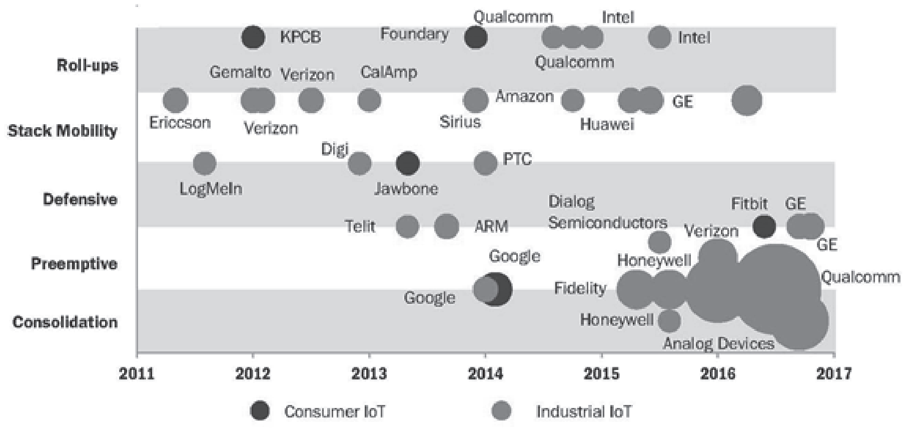

Figure 4: Mapping the IoT M&A Transactions (Source: Kumar et al., 2016:4)

The convergence between the digital (Internet) and physical (things) world has just begun, and these M&A deals only show the tip of the iceberg. The big techs and industrial manufacturers, once separated by the cyber-physical dichotomy, need to reconfigure their positions and strategies in this changing competitive landscape. Kumar et al. (2016:3) analysed both consumer and industrial IoT M&A and found that traditional technology companies like Google, Apple and Amazon are adding hardware products to their software and Internet stacks, whereas traditional manufacturers and OEMs are adding technology to their core capability hardware products. Industrial companies tend to acquire capabilities like device interface/management, data processing/ management, analytics, security, application enablement, enterprise integration, business process intelligence and simulation. Large corporations like Cisco, GE, Intel, Verizon and Qualcomm have been active investors in IoT companies across all layers of the stack. Figure 5 shows the acquisition and investment activities of Intel in 2016.

Company	Deal type (round)	Deal Value ($m)	Company Type
Yogitech	Acquisition	Undisclosed	Connected car
Itseez	Acquisition	Undisclosed	Connected car
ProGlove	Investment (Series A)	2	Wearables
Netspeed	Investment (Series C)	10	Technology vendor
K4Connect	Investment (Series A)	8	Wearables/medtech
Grand Chip Microelectronics	Investment (undisclosed)	Undisclosed	Technology vendor
Eazytec	Investment (undisclosed)	Undisclosed	Smart cities
Sigfox	Investment (Series E)	160	Service provider

* Investment deals are defined as any venture funding rounds, including by TMT companies' venture arms, and acquisitions of less than 50% of a company's value.

Figure 5: Intel IoT related acquisition and investment activities in 2016 (Source: Rakity et al., 2017:8)

Currently, the IoT industry is frequently associated with concepts like Industry 4.0, autonomous vehicle, and industrial robotics. This interest is influenced by the macro trend in digitalizing the manufacturing industry (e.g. 3D printing and smart manufacture), and the shift from mobile to artificial intelligence by the big techs. The *Financial Times* (Crooks, 2017) used the IoT Analytics data to argue that most IoT projects are in industrial sectors (Figure 6).

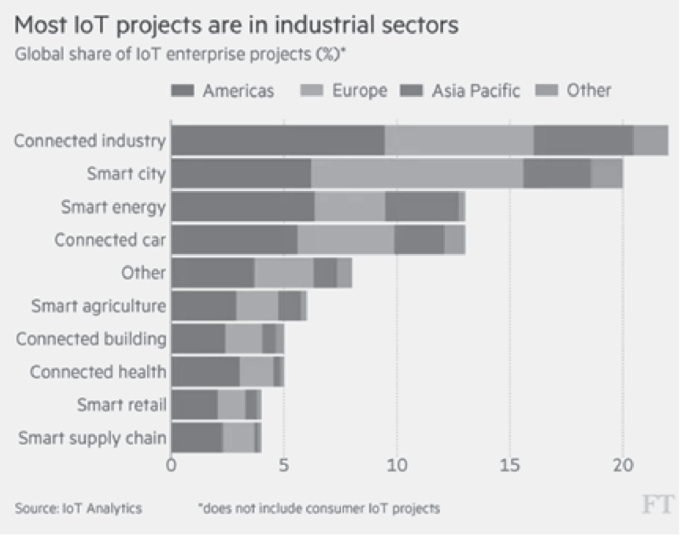

Figure 6: Global share of IoT enterprise projects (Source: Financial Times, 27 June 2017)

Figure 6 shows an estimation of over 50% of company spending on the IoT will come from manufacturing, transport and utility industries. For instance, Siemens has spent $15bn to buy US software companies since 2007, which is in line with the general M&A pattern of industrial manufacturers' acquiring upstream digital capabilities so as to secure their competitive positions during the coming IoT age.

This topic thus taps the growing public debates about whether the big techs are so powerful and profitable that legislators should intervene (Foroohar, 2017a, 2017b; Johnson, 2017). For instance, representatives of the downstream app providers, that are organised within the App Association[14] have argued that the European Commission officials seem to draft policies and patent guidelines that are favouring the upstream patent holders ("Greedy Big Techs"), rather than the downstream inventors of the "Things" who are the real innovators (Reed, 2017). On the other

[14] The App Association, with more than 5,000 members in the mobile economy, advocates for an innovation inspiring and rewarding environment and provides resources to help its members leverage their intellectual assets. (Source: http://actonline.org/ retrieved by 5 August 2017)

hand, IP Europe[15], representing the protection of intellectual property rights for a number of large software companies, objects to this description, and urges that the inventors (e.g., Ericsson and Nokia) of key IoT technologies, i.e. 5G, are also the innovators of IoT (Mingorance, 2017). Further, the licensing fee charged for gaining access to mobile networks is only a small portion (i.e., about 3% of the average sales price of a phone). Nevertheless, despite reassuring IP Europe's stance as a supporter of the open, transparent and inclusive standards system, this organisation has raised the concern that continuing the current system "would give rise to alternative, fragmented and proprietary Internet of Things technologies that owned by a few giant gatekeepers" (Mingorance, 2017). Therefore, the biggest challenge for regulators is not whether the big techs will win over the industrial manufacturers or the other way around. It is about how to prevent unfair competition and monopolies.

2.4.2 The policy drivers

Since the late 2000s, the US, the EU, China, Japan and South Korea all started IoT policy initiatives, but with different strategies. Generally speaking, the US Government has applied a leadership approach, stressing private sector coordination (such as in the IBM's Smarter Planet Concept since 2008, and the 2013 White House initiative-Smart America Challenge).

After the 2008 financial crisis, the world witnessed a re-polarisation process where Asian countries are still continuing to catch up. In today's fast-changing, digital industry, large multinationals come from both the West and East (Dolles et al., 2013). The Asian countries, in the beginning, took the position to challenge the leadership that used to be held by the US and Western Europe. For instance China, during the 12th Five Year Plan period (2011-2015), took a bold policy-imposed approach with generous financial instruments, focusing on R&D and demonstration projects to facilitate a rapid market formation process (even though, it was not as successful as expected). The world's first IoT pilot city, Wuxi, was created within this context and co-located with the first national IoT R&D centre. Other Asian economies also launched national IoT technology policies. For example, on July 6, 2009, Japan launched an i-Japan strategy, which focused on innovation in e-government, e-health, e-education, and green ICT for the smart environment and intelligent transportation system (IT Strategic Headquarters of Japan, 2009:4). At the end of 2009, the Ministry of Science and Technology of South Korea launched RFID and a"New IT Strategy" to advance the IoT infrastructure further (Xu, 2015:275).

EU research policies have for decades been designed to face the technical superiority of the US (Banchoff, 2002). Linked with the policy area Digital Agenda, the EU applied the European value approach, looking into the collaborative R&D, legislative, standardisation, privacy and security issues. After a failed attempt to harmonise the IoT governance structure in 2012, the EU shifted their focus for developing the innovation ecosystem. Within the EU, the technologically more

[15] IP Europe was originally launched by Ericsson, Airbus and France Brevets, and so far expanded to a network of over 20 R&D intensive European companies and research institutes from a variety of industrial sectors. The organisation aims to maintain strong patent protection for innovators and support fair, reasonable and non-discriminatory standardisation policies (Source: http://www.iptalks.eu/ retrieved by 5 August 2017).

advanced Member States began to launch national IoT strategies with financial instruments, such as the IoT UK project, the IoT Sweden initiative, the Industry 4.0 project in Germany, and the connected objects projects in France.

In 2015, the US Federal Trade Commission (FTC) did a study on IoT privacy and security, and suggested a self-regulatory approach, along with the enactment of data security and broad-based privacy legislation (FTC, 2015). So far this approach seems to have set the tone of IoT governance issues internationally. The EU has reframed the IoT policy in three key issues (a thriving IoT ecosystem, a human-centered IoT and a digital single market of IoT) within the digital single market priority and designated over €153 million direct funding in large-scale collaborative research and innovation projects in cross-cutting areas like active aging, autonomous car, and technological platform research. After investing ¥ 1.5bn in around 500 IoT R&D projects during 2011-2015, the central government of China has shifted its focus from taking the IoT as a government-led initiative to more a facilitator's role and supporting its national institutions and champion firms to compete internationally on R&D, commercialisation and standardisation issues.

If we observe this paradigm shift from a macro social context, what we are witnessing is a changing mode of production. The transition is not only a war without bullets in the business sphere, but it also challenges the existing laws, institutions and government regulations, such as spectrum and numbering policy, trust, privacy, security and consumer protection, as well as how to utilise IoT to achieve societal goals such as inclusive growth and circular economy (European Commission, 2016; Rose et al., 2015; Ziegeldorf et al., 2014). There has been a rising concern on whether the current regulatory framework is adequate in the perceived IoT future. For instance, the Korean government has established a "telecommunication strategy council" that aims to improve the general regulations of IoT-related issues (OECD, 2015:263). More regulatory actions to address the emerging IoT issues are to be seen.

From a shift by manufacturers and retailers driven by RFID electronic tags to the hyper-connected digital future society, and now the digitalizing industry and the data economy, the development path of IoT has not followed a predictable logic. What will the IoT be in the next decade, in 20 years, even 30 years? Will this term still exist, or will it have faded? There is no answer. If there is one thing in IoT that has been quite consistent over the time, it is the grand convergence of the physical and digital world. Underlying all the various technology, industry, and policy drivers of the IoT, this mega-force from the merger between atoms and bits has kept the IoT evolving. Therefore, full conceptualisation of the economic-geographic theory of the IoT takes this grand convergence of the digital and physical world as its moment of departure.

CHAPTER 3: THEORETICAL BACKGROUND

My "geography matters" thesis for the IoT adopts the concept of "context" as an entry and pursues it in terms of two themes. First, how does the adoption of IoT technologies redefine context? Second, how does context affect the production and adoption of IoT technologies?

The first theme was developed by integrating the digital-physical dimension from the geography of information literature with the local-global dimension from the geography of knowledge and innovation literature. The information sequence theory is applied to connect the spatiality of information with knowledge and innovation. I theorise the IoT as a container and a carrier of knowledge, especially tacit knowledge and discuss its spatial constraints. Using this framework, I develop how IoT redefines distance (in Section 3.1.3), how does the IoT redefine knowledge production/interaction that enables innovations (RQ1 in 3.3) and then develops the spatial characteristics of adopting the IoT technologies (RQ2). I label these spatial characteristics of adopting IoT as "contextuality of relevance and connectivity" and propose both *information system proximity* and *information network proximity* as the new spatial factors. I then lay out some of the possible implications for the spatial consequences of "contextuality" in organizing production and service activities (RQ2). Since up till now, society is still in its early phase of adopting the IoT technologies in consumption, business, and industry, this discussion is continued in Chapter 5.

The second theme is about the contextual factors regarding the innovation activities of IoT technologies. I carry out this theme in two stages: (1) the production of IoT applications (RQ3) and (2) the adoption of IoT services (RQ4). Since the production of IoT applications is a knowledge-intensive innovation activity, knowledge bases and proximity provides the theoretical entry for discussing the spatiality of innovation networks. The production of IoT applications often requires certain cross industry/sectorial interactions of knowledge and competences. Thus, I combine the insights from the intermediary role of KIBS to explain these multilevel dynamics. To facilitate the discussion on how contexts affect the adoption of the IoT services, I apply a user-centric characteristics-based approach to redefine its technology, products, and services as service characteristics. In this way, the IoT services can be understood in the context of its users' perceived values. Based on a review of current IoT adoption studies, I provide a framework of spatial factors for IoT service adoption by three different groups of users, i.e., individuals, industry and society. Even though the emergence of IoT is technology-industry driven, various policy initiatives that intend to facilitate the takeup of IoT are part of the institutional factors related to adopting IoT in society (RQ5). This aspect is approached from the angle of public policy and the creation of a new technologically based industry path.

THEME 1: HOW DOES THE ADOPTION OF IoT REDEFINE CONTEXT?

3.1 THE DIGITAL-PHYSICAL DIMENSION: GEOGRAPHY OF INFORMATION

In this sub-section, I focus on the spatiality of information flow, and propose an integrated view of the digital-physical space to understand how IoT redefines distance. Distance is no longer only a vector in the physical world. It is also a measurement of connectivity and interoperability. Based on this focus, I propose two digital proximities, namely, *information network proximity* (infrastructure) and *information system proximity* (architecture).

3.1.1 IoT IN A PHYSICAL WORLD-CENTRED DOCTRINE

Using the physical world-centred doctrine, there are typically two ways to theorise the geography of information. One way is to see information systems as digital infrastructures and illustrate its spatial distribution, e.g. the geography of an Internet/broadband infrastructure (Malecki, 2002; Malecki and Moriset, 2008; Tranos, 2013; Tranos and Nijkamp, 2013). The other way is to treat information as a commodity (for example, as digital products and services) and analyse the geographical factors during their production, transmission and consumption (Kellerman, 2002; Rami and Inkinen, 2008; Wilson et al., 2013; Wilson and Corey, 2000; Zook, 2002, 2005).

The first way is also to view information infrastructures as information highways. Applying this metaphor, the spatial effect is commonly described as "time-space compression" (Harvey, 1989:240) or "distortion" (Malecki & Moriset, 2008:219) of two contradictory forces: a centrifugal force (e.g. global cities) and a centripetal force (e.g. outsourcing or offshoring routine tasks to low wage areas). The dynamics between those two forces consequently can redefine the geography of competitiveness of firms, regions, and even nations. Harvey's "time-space compression" (Harvey, 1989) describes the modern transport and ICT's effect on time acceleration and reduction of the significance of distance. ICTs and other space shrinking technologies have brought great flexibility to business activities, so they can locate where they can benefit the most from reducing the transaction costs and economic externalities. As a result of business globalisation and technology advancement, places are increasingly connected as growing webs driven by corporations that seek knowledge and resources worldwide (Lorentzon, 1995). However, previous research has shown that geography matters for the information economy (Kellerman, 2002:1), and digitalisation has not created a completely dispersed economy; rather it has contributed to the distortion of economic space that has resulted in both convergences and divergences in the micro- to- macro scale of individuals, communities, and regions (Malecki & Moriset, 2008:219). This characteristic is proven by the geography of the information infrastructure, which is neither decentralised nor concentrated, but instead just complex (Kellerman, 2002:21). For example, Tranos (2013) compared the spatiality of Internet backbone networks in European regions with the airline network and concluded that the Internet infrastructure correlates with those regions with a high absorptive capacity.

Due to the further convergence of physical space and cyber space, the Internet is becoming a "Second Action Space" (Kellerman, 2014, 2016) for a broad range of human activities, such as shopping, banking, social interactions, entertainment, education, and even fraud and crimes, which were traditionally only performed in a physical space. This "Second Action Space" brings forth the second view, namely, information as commodity, e.g. applications, services, or products

(Kellerman, 2002:14). Information in its abstract form does not occupy space, but the producing, transmission and consumption of information are all dependent on "containers" which usually do occupy locations. The most common containers are the various digital devices, media platforms and humans. The transmission process is highly dependent on the network infrastructure, which is unevenly developed in the world. Similar to other products, the consumption, and dissemination of information and knowledge differ from place to place and that aspect relates to the context of use, such as language, culture, education, economic conditions, and more (Wilson et al., 2013; Wilson and Corey, 2000). Therefore, a seemingly placeless information commodity is dealing with location constantly.

The IoT systems often consist of both views. The IoT platform provides connectivity, manages data/devices, and deploys IoT applications. Except for the Internet, there are hundreds of IoT platforms that are specialised for business segments or application areas, such as Google's Cloud IoT, IBM's Watson, the open-source KAA, GE's Predix, Oracle's Integrated Cloud, Cisco's IoT Cloud, and Amazon's AWS IoT. IoT applications (a commodity) are blossoming in consumer, business and industry segments that range from smart home, smart mobility, smart health, smart public services, smart energy, smart city, smart manufacturing and more. These can be geographically dispersed, or geographically concentrated for a geographical fix or mobile sensors and devices. In this way, we are applying a physical-world centred view to understand the geographical aspects of IoT.

3.1.2 IoT IN THE DIGITAL WORLD-CENTRED DOCTRINE

Given the physical world-centred doctrine, we now can conclude that the space is compressed and distorted by digital forces. If we look at the other extreme - a digital-world centred doctrine, how is space defined there? If we see the digital space as a separated location where human activities operate (Hillis, 1999; Kitchin, 1998; Malecki, 2002), there is no sense of direction, no distance or place (Kwan, 2001:23). Space is unlimited but full of electric digital flows. These flows are not travelling freely, but rather are affected by how are they connected and how these flows interact with each other. Therefore, under the digital world-centred doctrine, the space is disrupted by the connectivity and interoperability of an IoT system. Connectivity is easy to understand, because without any connection, there is no electric digital flow. Interoperability in information technology is defined as the "ability of a system or a product to work with other systems or products without special effort on the part of the customer". Interoperability is made possible by the implementation of standards.[16] In social science, interoperability intended for system-to-system performance is also affected by social, political, and organisational factors that are crucial for digital governance (Gottschalk, 2009).

Therefore, interoperability is another type of connectivity, which is less about infrastructure, but more about the architecture of information systems. For instance, today there are hundreds of different IoT platforms. Not all of these platforms can interoperate with other platforms. In fact,

[16] This definition comes from the IEEE Standards Glossary (2010).
https://www.ieee.org/education_careers/education/standards/standards_glossary.html (retrieved by 2 July 2017)

due to different communication standards and intellectual property issues, the majority remain "islands", with very few being "open source". One development scenario is that one day, there will be a convergent communication standard for all IoT platforms, just like the Hypertext Transfer Protocol (HTTP) for today's World Wide Web. Or it can go in the opposite direction which then enhances further fragmentation of specialisation. A scenario that is in between can be oligopoly, such as the current Android/iOS divide in the mobile device platform and the Windows/Mac divide in the desktop laptop platform. So far, however, there is not enough evidence to support any of these assumptions.

3.1.3 IoT IN AN INTEGRATED WORLD VIEW

To fully understand the spatial characteristics of IoT, both doctrines are still too narrow. The physical world and the digital world are increasingly entangled as one. IoT illustrates the further integration of the digital and physical space where both intertwine to a degree where their separation no longer makes sense. I hereby propose an **integrated view of the digital-physical space**, where distance is no longer only a vector in the physical world. Distance is also a measurement of connectivity and interoperability.

This integrated view of digital-physical space contributes to the relational conceptualisation of the economic space in economic geography (Boggs and Rantisi, 2003; Yeung, 2005), by adding digital proximities. Distance is not only a measurement of the physical, institutional, social, and organisational proximity; it is also as a measurement of connectivity and interoperability, namely, information network proximity (e.g. an IoT network infrastructure) and information system proximity (e.g. IoT operational platforms). This relational conceptualisation is context-based, and thus provides theoretical connections to integrate the local-global dimension.

3.2 THE LOCAL-GLOBAL DIMENSION: THE GEOGRAPHY OF CONTEXT

Since the goal of IoT technologies is to provide "smart" services to human activities, the issue is not only about information flows, but more importantly about knowledge flows, especially tacit knowledge flows. In this sub-section, I turn first from the information flow to the knowledge flow and discuss the geography of knowledge and innovation. In the second part, I introduce the components of and the economic-geographic interpretation of context.

3.2.1 KNOWLEDGE, CONTEXT, AND THE GEOGRAPHY OF INNOVATION

Knowledge and learning, especially tacit knowledge, is the key determinant of the geography of innovation activities (Gertler, 2003). There are two kinds of knowledge: codified knowledge and tacit knowledge (Polanyi, 1966). Codified, also known as explicit or open knowledge, i.e., language, patents and formulas, can be universally accessed and easily transferred through long-distance communication (Cooke, 2008). However, tacit knowledge, also known as implicit, encoded knowledge, i.e. swimming, riding a bicycle and playing the piano, is difficult to produce and/or acquire through long distance. It is "best acquired experientially... its context-specific nature makes it spatially sticky, since two parties can only exchange such knowledge effectively if they share a common social context" (Gertler, 2003:79). Thus, the efficient transfer of tacit knowledge often requires contacts and trust, such as personal demonstration, learning by doing, and interactive learning (Lundvall, 1992). Whenever more codified information is universally easy to get access, tacit knowledge that is context-specific (less mobile) becomes more geographically concentrated (Asheim and Gertler, 2005; Feldman, 1994; Maskell and Malmberg, 1999). Knowledge-intensive activities are spatially sticky and thus are the stepping stone to regional specialisation (Asheim and Gertler, 2005; Feldman, 1994).

However, it is superficial to link codified knowledge to local and tacit knowledge and also to global knowledge (Faulconbridge, 2006), because all can be exchanged and move from local to global (Bathelt et al., 2004). Moreover, tacit and codified knowledge is transformative, which can be defined in terms of two processes, namely, externalisation from tacit to codified knowledge flow, and internalisation by moving codified to tacit knowledge flow (Nonaka et al., 2000). Cooke (2008) further argues that tacit knowledge may no longer be sufficient during knowledge realisation process because the growing importance of relational interactivity differs from the more traditional linear, vertical knowledge flow we are used to accessing. Therefore he proposed a third type - *complicit knowledge,* in order to perform the interpretative tasks necessary between tacit and codified knowledge. This third type of knowledge extracts useful information from tacit knowledge (spatial locations) and transforms it into codified knowledge. This distinction of knowledge types builds the foundation of space and place that relates to knowledge/technology diffusion and creates a place (innovative milieu) where a specific social-technological context is embedded.

Local buzz and global pipeline are both modern spatial patterns of innovation activities (Bathelt et al., 2004; Maskell and Malmberg, 1999). Firms integrate themselves into local clusters and international innovative networks to deal with technological upgrading (Ivarsson and Alvstam, 2005; 2011), diversification, and discontinuity (Boschma and Frenken, 2011a; Maskell and Malmberg, 2007), as well as to achieve economic externality (Asheim and Coenen, 2005; Balland et al., 2016; Carayannis and Wang, 2008). Consequently, the contemporary economic space is characterised by geographically concentrated knowledge-intense activities and the outsourcing or the offshoring of routine functions and tasks in production and service to low-wage locations (MacKinnon and Cumbers, 2007:196). Contexts also affect knowledge production. The relationship between tacit knowledge and social context is reflexive (Gertler, 2003). Research suggests that the impact of geographical proximity on innovation should be examined in relation to other types of proximity, e.g., the cognitive, organisational, social, and institutional (Boschma, 2005).

3.2.2 COMPONENTS AND THE GEOGRAPHY OF CONTEXT

Notwithstanding the reflexive relationship between tacit knowledge and context, the components and the geography of context are still poorly understood. Storper (2009) further developed the theory of context by extending the traditional logic of scale and scope to the structure of the actor's situation.

He defined context as "the structural component of context is defined by the division of labour and the networks in which the actor finds herself or himself, which has a decisive influence on the informational environment for the individual, hence her or his 'input' structure of cues and reference point" (Storper, 2009:13). What Storper pointed out is the importance of context (local and far away, as defined by the division of labour and networks) to the construction of the actors' situations for their social-economic actions. Since contexts also affect an actor's future prospects, these contexts may have intended long-term effects. Consequently, the architecture of the actor's context is the mixes between highly organised, but locationally fragmented, specialised contexts and market-oriented, but highly diverse and dense communication contexts (Storper, 2009).

3.3 Integrating the Digital-Physical Dimension and the Local-Global Dimension

This sub-section combines the digital-physical dimension with the local-global dimension to theorise the spatial characteristics of the IoT and develop the information sequence theory to connect the spatiality of information flow to knowledge creation and innovation. Based on the literature review in Chapter 3.2, it then theorises the IoT system as a producer and carrier of tacit knowledge, thereby complementing the role of humans in knowledge production and dissemination.

3.3.1 Bridging the Spatiality of Information with Knowledge and Innovation

The mechanism that links data, information, and knowledge to innovation is explained by Kellerman (2002) in the "*information sequence*" (Figure 7). He points out that information in nature is transformative, communicative, and indeed follows four basic sequential processes:

a) Data to information via meaningful patterns and context;

b) Information yields information by the interaction, for instance, between people speaking or writing;

c) Information to knowledge by its application. However, knowledge also produces information and knowledge that is required for the additional development of information;

d) Tacit knowledge, codified knowledge, and information are the bases of innovation and innovation create new information and information technology.

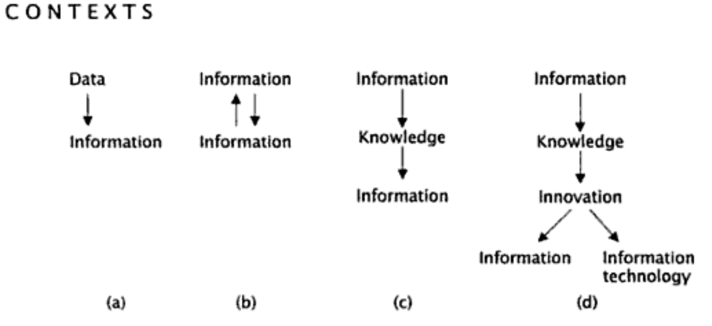

Figure 7: The Information Sequence (Source: Kellerman, 2002:4)

As the above figure illustrates, information is transformative and communicative, but the transformation from information flow to knowledge requires application. Application indicates that someone/something collects and interprets the information for a purpose, so that it can become knowledge. Therefore, application consists of motivations and actors. This transformation is also context-based. As I discovered in the spatiality of information flow, both information system proximity and information network proximity affect this process. These digital proximities may also constrain the creation and dissemination of the knowledge.

Connecting the local-global dimension, which explains the more tacit type of knowledge and the transformation between tacit and codified knowledge, creates the dynamics known as local buzz and global pipeline as spatial patterns of knowledge-intensive activities. This line of literature considers humans as the prime creator and container of tacit knowledge. Here I combine these two dimensions by adding IoT as a producer and container of the tacit knowledge. When the production of knowledge, especially the more tacit type of knowledge, expands from being human-centred to a combination of human and non-human actors, then social economic activities are accordingly transformed into a more complex division of labour in time and space. As a result, both the digital-physical and local-global dimensions constitute the spatial dimensions of the IoT.

3.3.2 IoT, TACIT KNOWLEDGE, AND CONTEXT

The adoption of IoT technologies can have a profound influence on both producing and disseminating tacit knowledge, but in a way that that dissemination is different from how humans do it (see Table 6).

Table 6: Tacit knowledge of different containers, spatial constraints and characteristics (Source: Author)

The container	The production of tacit knowledge	The use of tacit knowledge	The media of dissemination	Spatial constraints for dissemination	Spatial characteristics of interaction
Humans	By practice and sensing	By humans	Personal demonstration, learning-by-interactions/doing	Cognitive, organisational, social, institutional and geographical proximity	Local buzz and global pipeline
IoT	By programming, sensing and machine learning	Providing information and services to human activities (**relevance**)	Algorithm, software and information networks	Information system proximity (interoperability) and Information network proximity (**connectivity**)	Contextuality of relevance and connectivity

Humans produce tacit knowledge by experiencing and sensing (Gertler, 2003), while IoT technologies can enable the production and acquiring of tacit knowledge via programming, sensor technologies and machine learning. For instance, the Nest Learning Thermostat is a programmable, self-learning, sensor-driven, Wi-Fi-enabled smart home IoT application. It can automatically learn a family's preferences, daily routines, and season changes. In just one week's learning, it can program itself to adapt the household's energy schedule to the family's lifestyle, so it optimises energy consumption of that household. The household life style is a more tacit type of knowledge that can only be acquired by experiencing it. In this case, the IoT applications become the producer and the container of that tacit knowledge. This is one aspect of how IoT enables innovation. The word "smart" is often used to describe this feature of the IoT, although the degree of "smartness" can vary to a large degree. Nevertheless, based on the current development pace of technological advancement, we can foresee an increasing degree of smartness of these IoT applications and a growing number of smart IoT devices /systems that will be to engage in the creation and dissemination of the more tacit type of knowledge.

Since the transmission of tacit knowledge between individuals cannot be done verbally or via written instructions, humans have to disseminate this kind of knowledge through personal demonstration and learning by doing. This technique of delivery does not apply to IoT systems. Once tacit knowledge is produced, it can be immediately disseminated through algorithms and software in information networks, without having to demonstrate and practice that knowledge from one computer to another. For instance, mastering the board game GO usually will take a person years of practice, and one person's mastery does not automatically transfer to apprentices. They still will need to acquire the skills by years of practices. It is not the same for machine learning. Once AlphaGo acquires the skills of playing GO, this ability can be shared instantly with other computers that are compatible in computing power. However, there are still limitations. As explained in the discussion on the spatiality of digital space earlier, ***connectivity***, including network connectivity (infrastructure) and architecture connectivity (interoperability) affect knowledge dissemination. I define them as *information network proximity* and *information system proximity*. Information network proximity and information system proximity are less geographically constrained than humans are, but can be still affected by organisational, social, and institutional contexts. A recent study of the Internet shows that both physical distance and different relational proximities are significantly associated with the actual spatiality of the Internet (Tranos and Nijkamp, 2013).

Applying Storper's (2009) definition of context, I discuss what is new about the IoT in the division of labour and the actors' network. The concept of division of labour produces insights into today's increasingly specialised nature of knowledge production (Pavitt, 1998). The division of labour addresses the importance of coordination and motivation due to the growing interdependency caused by an increasing degree of specialisation in the global economy. Specialisation is preferable because of comparative advantages. However, specialisation is affected by coordination and motivation. The IoT contributes to the large scope of multi-agents of information providers and receivers, and as such, the decentralisation of the information structure provides fertile ground for further specialisation by the information collector, producer, mediator and user. This contribution leads to innovations in motivation. IoT applications, via automation/telematics, increases the efficiency of current activities (e.g. smart industry), and creates new types of digital services (e.g. autonomous driving). However, solving only the motivation aspect is not enough; a new way of coordinating activities is also required. IoT further opens the communication channel from things to things, things to people and computers to things. The IoT platform is the physical part of such coordination, while the digital part is carried out by the advanced information processing capabilities of chips, sensors, and computers, and, more importantly, the people who programme them. The condition of specialisation is accordingly modified by the new IoT technologies. Because of automation and telematics, things thus become "smart". By adding smart things as non-human actors and contributors of knowledge creation, more specialised actors become involved in social economic activities.

These constraints are also affected by the division of labour. The creation and dissemination of tacit knowledge is constrained by human contexts. For IoT systems, the usage of tacit knowledge is eventually intended for humans: providing useful information and services to human activities. A car does not need to know how to drive, unless autonomous driving is a valuable service to its users. This example shows that the value creation of IoT lies in such division of labour, which provides motivations to connect "things" to the Internet. I define it here as ***relevance***. Relevance provides a key stepping stone towards a sound business model of IoT services.

Putting the above discussions together, *relevance* and *connectivity* constitutes the spatial characteristics of adopting IoT technologies, which I define as "**Contextuality**" (Figure 8). The **contextuality of relevance and connectivity** includes both the local-global dimension and the digital-physical dimension. Relevance points out why to connect the local things to the global Internet. Thus, it is on the local-global side. Relevance explains further the motivations underlying the division of labour. It is, thus, crucial to the value creation of IoT services. Connectivity is a crucial part to coordinate an IoT system. Connectivity describes how to connect physical things to the digital Internet (e.g. network connectivity) and how to enable interactions between things and things or things and people (e.g. interoperability). It is on the digital-physical side.

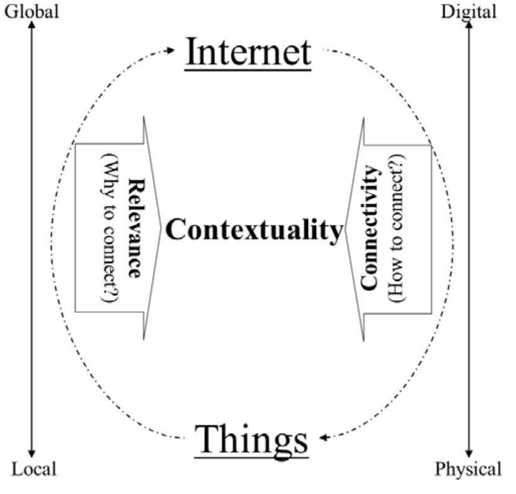

Figure 8: An illustration of the spatial characteristics of adopting IoT technologies (Source: Author)

3.3.3 The spatial consequences by adopting the IoT

A straightforward result of the mass adoption of IoT technologies might be the outsourcing and offshoring of routine tasks to IoT systems or the co-handling of advanced tasks by artificial intelligence assisted human activities. In theory, this focus could reduce the effects of geographical proximity. Instead, both information system proximity and information network proximity could have an increasing impact on the spatial structure of many economic activities. This deduction is of course a speculative one. However, there are some indications that support it. The current structure of mobile devices, e.g., Smart phones and tablets, are largely affected by Android and iOS factions, rather than other kinds of contextual factors. In production, the geographical fragmentation of such production systems is increasingly on the fine-grained level of tasking rather than on the subsystems and functions (Cooke, 2017; Grossman and Rossi-Hansberg, 2008). The rise of the IoT age thus has the potential to reinforce such "context-based" coordinating and motivating of social-economic actions on a global scale and further still, the geographically specialisation of tasks over functions.

Such a scenario is described by Storper (2009) as a great transformation of "distributed contexts" wherein new technologies would facilitate coordination and motivation that would greatly alter actors' situations in four respects. First, new technologies would redefine the current intra-organisational borders, e.g. the transformation from big vertically integrated producers to networked heterogeneous production units. Second, physical geographical distance would play a lesser role for intra- and inter-organisational relations. Third, the boundaries between the formal and informal processes of coordination, contracting, and monitoring would be modified, e.g., quasi-formalised to combine both long distance and flexibility in deal making. Last, information would be acquired through "global pipelines" (Bathelt et al., 2004). These "distributed contexts" are not yet a reality, just currently a vision.

What Storper did not mention is the service perspective. Since the value of the IoT is the providing of useful information and services for human social economic activities, it can also contribute to the servitisation of manufacturing, e.g., Industry 4.0 and smart manufacturing (Lee et al., 2014). Since many economic activities are increasingly carried out by tasks, such structure will further blur the boundary between goods and services, which pushes further forward the trend of global economy transiting from being goods-oriented to solutions-oriented (Chesbrough and Spohrer, 2006; Spohrer and Maglio, 2008). The value thus shifts from tangibles (e.g., the physical goods and their infrastructures) to a combination of tangibles and intangibles, software and hardware as well as products and services, such as Amazon Echo, Nest Learning Thermostat and the Tesla Autopilot car. This transformation can lead to new business models that are driven by predictive analytics and cyber-physical systems, e.g., sensors for service and digital charged products (Fleisch et al., 2014). Future competitiveness, accordingly, is not only defined by the investment in digital infrastructure, the causality between knowledge thickness and geographic concentration, but also how much the firm, the region, or the nation is able to relate its specialisation to the distributed contexts of tasks, and how well they can handle advanced data science and information processing to generate knowledge and innovation from the "context-based" coordinating and motivating of economic actions.

THEME 2: HOW DOES CONTEXT AFFECT THE PRODUCTION AND ADOPTION OF IOT?

3.4 CONTEXT AND THE PRODUCTION OF IOT APPLICATIONS

From a knowledge production point of view, the information sequence theory (explained in Section 3.3.1) shows that knowledge and information are the dual bases of innovation, and innovation creates new information technology. The production of IoT applications, accordingly, can be understood as knowledge-intensive innovation activities that are spatially affected by knowledge base (3.4.1), and their various proximities (3.4.2). Since the IoT applications, especially consumer-oriented applications, are digital re-inventions based on existing physical products, such as the smart refrigerator, connected car, smart camera and connected Nespresso coffee machine. The development of such applications often requires a variety of knowledge and competences that cross the current industry and sectorial boundaries. This process can involve interactions with a multi-framework of heterogeneous actors with a different geographic reach. The *knowledge base* and proximity theory are not sufficient to explain such multilevel dynamics. Section 3.4.3 turns to the intermediary roles of KIBS functions as the drivers of knowledge dynamics in multilevel contexts. Section 3.4.4 then discusses the spatial implications for the production of IoT applications.

3.4.1 KNOWLEDGE BASES AND THE SPATIALITY OF INNOVATION NETWORKS

The typology of *Knowledge bases* provides an alternative conceptualisation of knowledge. Since knowledge creation almost always requires both tacit and codified knowledge, the binary dichotomy of knowledge is too narrow to let us fully understand the spatial dynamics of knowledge creation in innovation processes (Asheim et al., 2011; Nonaka et al., 2000). Another way to categorise knowledge, however, is by its industrial applications, namely, the analytical, synthetic, and symbolic knowledge (Asheim, 2007; Asheim et al., 2007; Asheim and Gertler, 2005; Asheim and Hansen, 2009).

An *Analytical knowledge base* is science-based (know why), e.g. drug development. It refers to knowledge creation that is based on formal models and the codification of scientific knowledge (deductive). It often involves collaborations in specialised research labs and institutions and produces highly abstract codified knowledge that is universal. A *Synthetic knowledge base* is engineering- based (know how), e.g. mechanical engineering. The creation of synthetic knowledge requires re-inventing existing knowledge through new combinations using problem solving and customisation (inductive). Producing this type of knowledge requires interactive learning with other actors, such as suppliers, customers, and users. The result is partially codified knowledge with a strong tacit component that is more contexts specific. A *Symbolic knowledge base* (know who) is arts-based, e.g. fashion design. This type of knowledge is about creating meaning, symbols, images, human desire, and intangibles through use of the creative process in studios and project teams. Symbolic knowledge thus implies strong context specificity. Therefore, spatial proximity is least important for an analytical knowledge base, but most important for a symbolic knowledge base (Asheim, Coenen and Vang, 2007; Asheim and Hansen, 2009).

The limitation of this typology is due to the fact that most knowledge creation processes involve the combination of two or all of the knowledge bases (Asheim et al., 2011). Nevertheless, due to the different degree in place sensitivity of each knowledge base, this typology does provide a useful analytical tool for studying the spatiality of innovation networks. Martin (2013) conducted a social network analysis on the cooperation and knowledge exchange of several regional industries in Europe, and his conclusion supported the idea that analytical industries are less constrained by geographical proximity, while the knowledge sourcing of synthetic industries tends to be more restricted in terms of national regional networks of suppliers and customers and their communities of practice. Symbolic industries rely more on localised networks that can be temporarily and flexibly structured. The differentiated knowledge base is also used to analyse the geographical structure of the global innovation network (GIN). Liu et al. (2013) studied both intra-firm and inter-firm GINs and discovered that knowledge base affects how GIN is organised and identified two forms: The globally organised model and the locally organised model.

3.4.2 Proximity and the geography of innovation networks

Different proximities between organisations can both reduce uncertainty and smooth coordination in various respects, and thus are considered to facilitate the generation of innovation, learning and collective knowledge (Boschma and Frenken, 2010; Gertler, 2003; Morgan, 2004). Proximity is a useful analytical concept to use to explain the intra-/inter-organisational structure of innovation networks (Boschma and Frenken, 2010), although it can be interpreted and defined in many ways. According to Boschma's (2005) definition, there are five types of proximities (but not restricted to these five types): Cognitive, organisational, social, institutional and geographical. For innovation, proximity is not the closer, the better; in fact, either too little or too much proximity may be harmful to innovation. Taking a proximity perspective to the spatial evolution of innovation network indicates that organisations that are proximate in some/or all of their dimensions are more likely to connect (Boschma and Frenken, 2010).

Firstly, *cognitive proximity* indicates the knowledge gap. Organisations identify, search for, interpret, and exploit new knowledge to innovate, while the effective sharing and transfer of knowledge is determined by their absorbing capacity (Cohen and Levinthal, 1990). Organisations located within the same knowledge base are more likely to learn more from each other. Cognitive proximity can also be understood as a measurement between two organisations' knowledge bases. Too much cognitive proximity may lead to a lack of sources for novelty, while too little may cause misunderstanding. A possible solution is to have a common knowledge base with diverse, but complementary, capabilities available (Boschma, 2005).

Secondly, *organisational proximity* illustrates the control gap in the intra- or inter-organisational arrangement, which can range from extreme informal economic exchanges to formal joint ventures and franchises and the hierarchically organised forms (Williamson, 1985). Too little organisational proximity may encourage opportunism, while too much will lead to bureaucracy.

Thirdly, *social proximity* refers to the socially embedded relationship gap. Social embeddedness has been extensively researched by sociologists and organisational studies (Granovetter, 1985; Uzzi, 1997). The basic idea that underlies the embeddedness literature is that economic relations are always socially embedded, so social relations, i.e., friendship, kinship and common experience, can affect economic outcomes by adding trust and avoiding conflict. Economic geographers have applied such thinking to studying the abilities of organisations to engage in innovation networks. This type of proximity is crucial, especially for informal knowledge exchange and knowledge spillovers, such as epistemic communities, invisible colleges, and communities of practice. Too little social proximity encourages opportunism, while too much provides little economic rationale.

Fourthly, *institutional proximity* describes the institutional gap on a macro level, including formal laws and regulations as well as information norms and values. Institutional proximity provides stable conditions for interactive learning. Too little institutional proximity results in opportunism, while too much will lead to lock-in and innovation inertia.

Lastly, *Geographical proximity* is the physical distance gap. It can be defined in an absolute manner as the miles between two organisations, or in a relative manner as the travel times between the two. A key question is whether geographical proximity (co-location) is still necessary for tacit knowledge exchange in today's globalised world (Gertler, 2003; Malecki, 2010). Rallet and Torre (1999) argue that non-local relations should be encouraged to facilitate tacit knowledge exchange, such as using temporary co-location instead of permanent co- location. Another example is the Multinational Enterprises (MNE) whose subsidiaries act as nodes that are embedded in a variety of local contexts to access diverse knowledge bases and integrate them into new competences (Mudambi and Swift, 2011). Boschma (2005) claims that geographical proximity *per se* is neither a necessary nor a sufficient condition for learning and innovation; however, it still facilitates innovation activities by strengthening the other types of proximities. Jansson (2008) investigated the Internet industry in Stockholm, Sweden, and found out that due to the importance of dense informal interpersonal networks, close geographical proximity of firms in the Internet industry facilitates the search for new customers and collaborators. Too little geographical proximity may cause no spatial externalities, but organisations that are too close may lead to a lock-in problem. When solving lock-in, a combination of local buzz and extra-local linkages (geographical openness) is suggested.

Proximity sheds light on an evolutionary approach to regional development and new industrial emergence (Boschma and Frenken, 2010). The concept of "related variety" refers to the diversity of industries in a region that are thereby cognitively related (Frenken and Boschma, 2007). Firms consist of organisational routines; over time can diversify into technologically related fields. Organisational routines will contain primary learning-by-doing knowledge and tacit knowledge. Thus, their routine replication and recombination can have a strong regional bias (Boschma and Frenken, 2011). This process of new industrial emergence is accordingly conditioned by a region's pre-existing regional capabilities and technological relatedness (Frenken and Boschma, 2007; Martin, 2010; Neffke et al., 2011).

3.4.3 KIBS AS DRIVERS OF MULTILEVEL KNOWLEDGE DYNAMICS

The above two sub-sections suggest that the spatial evolution and structure of the innovation network can be affected by differentiated knowledge base, or facilitated by various geographical or non-geographical proximities. Proximity describes the likelihood for organisations to connect based on some kind of shared similarities, either by being in the same knowledge base, or having similar organisational and institutional settings. However, this perspective downplays the intermediate roles that a special type of actor can play to facilitate cross-boundary learning and innovation driven more by difference than by similarity. That is the KIBS function.

KIBS are highly associated with the creation and dissemination of knowledge, which is essential for society to transit into a knowledge economy. KIBS are intermediary firms that specialise in knowledge-screening, assessment, and evaluation and will trade professional consultancy services (Consoli and Elche-Hortelano, 2010). Muller and Doloreux (2009) define KIBS as service firms that are characterised by high knowledge intensity and services to other firms and organisations, services that are predominantly non-routine. Strambach (2008) points out that KIBS are developing into a knowledge-processing and knowledge-producing industry.

Due to the KIBS' heterogeneous nature, both its definition and classifications can vary due to different purposes [17]. Regarding technology development, a more accepted way to categorise KIBS was introduced by Miles et al. (1995:29). They divided KIBS into P-type (Traditional Professional Services) and T-type (New Technology-Based). P-type refers to more advisory services, such as marketing, advertising, management consultancy, and legal and environmental services. T-type refers to technical services, such as computer networks, telematics, some telecommunications, software, technical engineering, and R&D consultancy.

Research shows that KIBS are actors of knowledge transformation (Bryson and Daniels, 2007; European Commission, 2014; Gallouj and Zanfei, 2013; Ke et al., 2014; Lee et al., 2014; Malecki, 2010; Muller and Zenker, 2001). Den Hertog (2000) argues that the KIBS function as facilitator, carrier, or source of innovation, and some KIBS indeed also function as co-producers of innovation because of their almost symbiotic relationship with their client firms. They pointed out the importance of relationships and interactivities in a KIBS network with the other actors during the innovation process. That importance is due to the "intangibles", as he (2000:491) puts it "in addition to discrete and tangible forms of knowledge exchange, process-oriented and intangible forms of knowledge flows are crucial in such relationships." Other than technologies, the importance of these "intangibles" in their relationships and interactivities can shed light on our inquiry into the factors that facilitate interactive learning between heterogeneous actors. In Wood's (2005) service informed approach, he further categorises those factors into three aspects and extends the intangibles to include knowledge flow to develop knowledge, learning and trust.

Wood (2005) claimed that competitiveness is more driven by knowledge-intensive service functions in the complex private and public sectors nexus rather than where the technologies are actually invented. He (2005:432) was provoked to view innovation as a service-based process because any successful technological innovation includes a bunch of specialised service expertise, as well as the processes and relationships that characterise it. These include: 1) the interactivity between sectors and firms; 2) orientation to market outcomes; and 3) the importance of intangibles (e.g. knowledge, learning, and trust). The service-informed approach emphasises the KIBS functions in the complex private and public sectors nexus and the interactivities among sectors and firms, which is helpful to help explain how the heterogeneous actors do interact on multiple levels.

[17] According to NACE rev.1.1, KIBS is defined as having three groups: 1) computer and related activities (72); 2) Research and development (R&D) (73) and 3) Legal, technical and advertising (74.1-4).

Strambach (2008) further argues that KIBS are the drivers of knowledge dynamics in multilevel contexts, such as on the firm, sectoral and territorial levels. One reason is due to the convergent tendency (Toivonen, 2004) of a "composite" nature of knowledge products that the KIBS sell, which range from synthetic (e.g. technical service), symbolic (e.g. marketing and advertising service) to an analytical knowledge base (e.g. R&D service). The second reason is the way KIBS produce knowledge. The KIBS operate in complex horizontal and vertical knowledge domains (Malerba and Orsenigo, 2000). For example, their technical services come across horizontal information communication and production domains, as well as vertical automotive, chemical, or finance domains. KIBS operate across different knowledge phases that range from exploration and examination to exploitation (Cooke, 2005) (see Figure 9). Due to all of these cross-cutting and composite characteristics of KIBS activities, project-based, *ad hoc* development of new knowledge is the norm for KIBS firms. In this way, KIBS can be identified as the drivers of knowledge dynamics in a multilevel context.

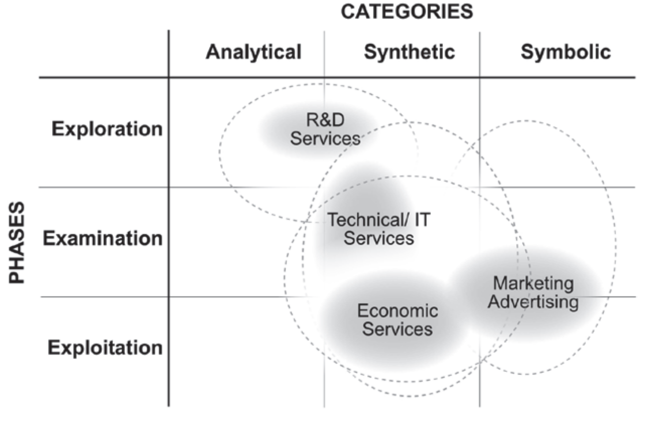

Figure 9: The focal points of KIBS sub-sectors in the different knowledge categories (Source: Strambach, 2008:159)

Due to this multilevel complexity of KIBS activities, it is more difficult to illustrate their spatial dimension in KIBS innovation networks (Muller and Doloreux, 2009). Studies do show the co-agglomeration of producer services and manufacturing (Jacobs et al., 2014; Ke et al., 2014). On the other hand, the evidence also supports the notion that regions are seedbeds or incubators for the foundation of KIBS, but this notion also depends on the specific techno-economic and institutional structure of the region (Koch and Stahlecker, 2006; Wood, 2005).

3.4.4 Spatial implications for the production of IoT applications

Applying a *knowledge base* typology, the development of IoT platforms involves intensive R&D using network and communication standardisation. Thus, it is more of the analytical type, while the production of IoT applications tends to be more synthetic knowledge based, since it is intended to apply ICTs for the re-invention of physical products and systems, e.g., connected car, smart transportation, smart grid and industrial IoT. However, this observation is not absolute. For some consumer-oriented applications, such as smart home and wearables, design plays an important role in the value creation. Therefore, the *symbolic knowledge base* is also required. Smart health applications can require all types of knowledge bases. Some IoT applications (e.g., smart infrastructure) are also naturally more place-sensitive than others due to their deep integration with local governance and infrastructure systems, especially for some smart city services and smart public transportation services. For the development of this type of services, local knowledge of the existing organisational and institutional relationships, as well as the local culture and the citizens' needs are as important as the technology, if not more so. Overall, the development of IoT applications is more spatially constrained than that of IoT platforms. Nevertheless, the current fragmentation of IoT platforms may indicate the rising importance of information system proximity when developing IoT applications. Therefore, from a *knowledge base* perspective, the spatial patterns of developing IoT applications can be rather complex.

One way to illustrate such spatial complexity is to view it by the distribution of its value chain (Chen, 2004; Zaheer and Nachum, 2011). So far, the value chain of the IoT industry is still under formation, so there is lack of enough evidence to run an analysis. However, for most consumer-oriented IoT applications, such as smart home devices and smart personal wearables, one possible future scenario would be one like today's smart phone industry. Currently, the global smart phone industry features two dominating operational systems, Google's Android and Apple's iOS worldwide, while the production of applications, i.e. a large number of smart phone "apps" are reconfigured in the more "distributed platforms" model of a global production framework (Cooke, 2017) (see Figure 10). Synthetic design and flagship markets take the high-end of the value-added chain, symbolic design and original design manufacturing stand in the middle, while contract manufacturing is situated at the bottom. Regions and countries then determine the division of labour according to their specialisations along the value chain. For instance, Silicon Valley, London, Toronto, and Malmö are specialised in the design of applications, while India, Ireland, and Israel are specialised in network architecture building. In this way, we can run a precise analysis by applying the production point of view.

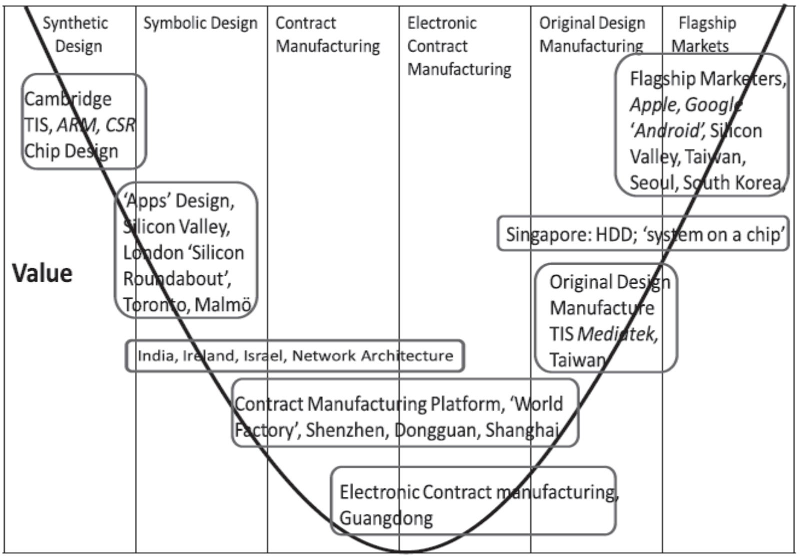

Figure 10: "Smiling Curve" of value in ICT Global Innovation Network (GIN) (Source: Cooke, 2017:20)

Another way to see the development of IoT applications clearly is from the service point of view. Since this process may involve a combination of knowledge and expertise in software, hardware, service, telecom infrastructure and more, it requires a co-innovation of the actors and crossing industrial, sectoral and geographical domains. One way to adapt to this multilevel knowledge creation is to form a temporal and flexible network of the actors that is "project"-based. In this type of innovation network, the KIBS role would be crucial to facilitate interactive learning of the multilevel dynamics, and also facilitate a related variety that transcends the geographical boundary through both local presence and international reach via contacts and clients. This aspect is discussed further in Article 3.

3.5 Context and the adoption of IoT services

No matter which form in which the IoT applications or systems are organised, for their adopters, there must be something that is valuable to them. These values can range from simply being cool and bringing convenience (individual), to increasing actual productivity and reducing costs (organisation), or tackling societal challenges, such as sustainability, an aging population and so on (society). These values are different for different levels of contexts. To discuss the adoption issues, I begin with a re-conceptualisation of the technology, products and services by applying a characteristic perspective. Then I lay out the insights regarding the contextual factors for possible IoT service adoption.

3.5.1 A characteristic approach for conceptualising service and innovation

Today we are living in a post-industrial era where the boundary between goods and services continues to blur. This shift in economic reality calls for a re-conceptualisation on services (or goods). The re-conceptualisation of goods and services for the characteristics-based approach is derived from Lancaster (1966), who assumes that "The chief technical novelty lies in breaking away from the traditional approach that goods are the direct objects of utility and, instead, supposing that it is the properties or characteristics of the goods from which utility is derived" (Lancaster, 1966). In other words, Lancaster defines a product (goods or services) as a set of characteristics. This different definition became the starting point for the construction of the Saviotti-Metcalfe framework (see Figure 11).

$$
\begin{array}{ccccc}
\text{Process characteristics} & & \text{Technical characteristics} & & \text{Service characteristics} \\
\begin{pmatrix} Z_2 \\ Z_2 \\ \vdots \\ Z_r \end{pmatrix} & \longleftrightarrow & \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{pmatrix} & \longleftrightarrow & \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_m \end{pmatrix}
\end{array}
$$

Figure 11: Relationship between process, technical and service characteristics (Source: Saviotti and Metcalfe, 1984:144)

In order to describe the technological outputs, they operationalised the approach by using technological paradigms and trajectories theory (Dosi, 1982), and defined three sets of characteristics: 1) technical characteristics, i.e., the technical features of the product; 2) service characteristics, i.e., the services performed by the product; and 3) process characteristics, i.e., the methods of producing the product. These three sets of characteristics are then related through patterns of mapping that offer the efficiency as a set of technical characteristics that can supply a certain desired level of services.

In this characteristics-based description, a product has a certain technology, which is the output of a producer and at the same time is the input to a user as service characteristics. Hence, the technological characteristics described the internal aspects of the technology, while the service characteristics measure the service performance (Saviotti, 1985). On the other hand, all products are made through a process, and within that process, there are certain process technologies that are independent of the final characteristics of the product. These process characteristics can be tangible, such as a plant, and intangible, such as a brand and patents, human resources, and organisational resources (Saviotti, 1996). Thus, the product and its process technology cannot be completely separate. Their framework becomes the foundation for the creation of the Gallouj-Weinstein framework (1997).

Searching for a general theory to explain the service innovation process, Gallouj and Weinstein (1997) proposed a representation of a product/service as a system of characteristics and competences. Their framework (see Figure 12) differs from the Saviotti-Metcalfe framework in several ways. First, the vector of service characteristics is defined as the final users' value instead of the service performed by the product. This change in definition there by shifts the focus from being "product"-centred to being final user-centred.

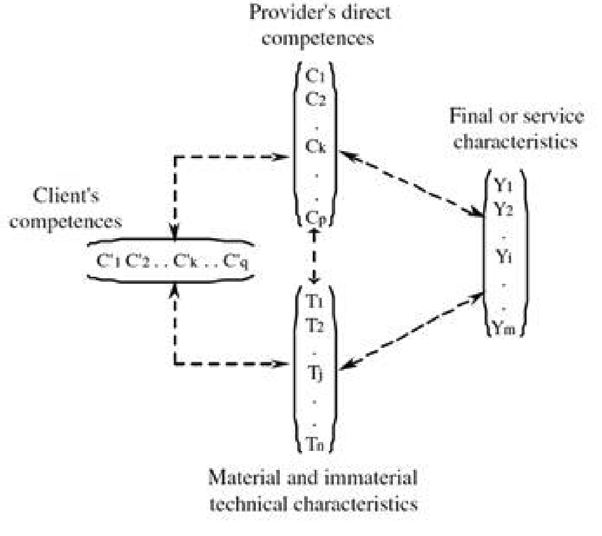

Figure 12: A generalised form of the Gallouj-Weinstein Framework (Source: Gallouj and Savona, 2009:164)

Secondly, the "competence" mobilised by service providers is added as the fourth set (vector) of the characteristic. Competence is defined as the ability and knowledge embodied in the technical characteristics. Gallouj and Weinstein argued that the provision of services is the result of a utilisation of tangible/intangible technical characteristics (including competence) and the mobilisation of those competences by service providers. Related to this change, the set of process characteristics is replaced by the client's competences. The argument for this major operation is the simultaneity of service activities. Simultaneity refers to the production and consumption of a service that occurs at the same time. Therefore, the separation of product and process is no longer a useful analytical tool. Instead, Gallouj and Weinstein highlight the clients' participation in the service relationships. This phenomenon is particularly true in knowledge-intensive services like education, consultancy, and health care. The self-service option in retail illustrates its extreme form. Gallouj and Weinstein asserted that "Whatever term is used (interface, interaction, co-production, 'servuction', socially regulated service relationship, service relationship), this link between service provider and client is the most important element missing from the notion of the product put forward by Saviotti and Metcalfe" (Gallouj and Weinstein, 1997:541). However, these process characteristics, although being downplayed, do not completely disappear. They are contained in a set of "technical characteristics". For this reason, this set of technical characteristics was renamed the material and immaterial technical characteristics.

Given the logic of this framework, innovation is defined as the changes that impact the vector(s). Therefore, innovation is a process instead of an outcome, and the framework can be used to describe cases at the micro level. The Gallouj-Weinstein framework has been used to map the innovation process for knowledge-intensive services and later it was also applied to public services, such as postal service and health care (Djellal and Gallouj, 2005). In recent years, their framework has been extended to meet the new challenges in service research. De Vries (2006) stressed the networked effect of providers, which responded to recent innovation trends in the networks of organisations and the distribution of services. Another extension is the introduction of the public authority's role into the framework, which was done by Windrum and García-Goñi (2008).

The characteristic approach provides a user-centred, service characteristic centred view of technology, products, and services in an integrated framework. This framework includes both the technological and non-technological aspects of deploying innovation and encompasses the interactions between service providers and users. This manner of defining technology, innovation, products, and services is helpful when solving some of the conceptual difficulties related to the adoption of IoT. Since IoT can be adopted as a device, a product, a service, or as an information system, it can cause confusion to theorise the research object. Using the characteristic perspective, no matter which form the IoT technologies take, they are defined as service (service characteristics) that can then be directly linked to the perceived values for their adoption.

The perceived value of adopting IoT services can vary based on its adopters. On the individual level, it can bring convenience (e.g., a smart refrigerator, smart coffee machine), help that improves health (e.g., smart health wearables), assist with household management (e.g. smart home) or just be fun and cool. On the organisation and industry level, the value can be to improve productivity, reduce costs, or bring new business models (Riggins and Wamba, 2015). For society, the benefits are identified in general as contributions to sustainability, economic growth and/or addressing societal challenges, such as an aging population, inclusive growth, public health and related needs/tasks.

3.5.2 Different levels of the contexts for IoT service adoption

The adoption of new technologies is not an exogenous factor, but rather an inherently social-cultural activity that depends on its contextual setting (Martin, 2002). Schwanen and Kwan (2008) pointed out that space-time constraints, such as the type of digital services, the persons involved, technologies, and the socio-physical context are influencing the use of digital technologies in daily life. For instance, the Internet and mobile telephony are likely to adapt or perish when placed in differing contexts when they take on dissimilar attributes that are location-dependent (Wilson et al., 2013). The users of IoT services can be divided into three main groups: individuals/households, organisations/industry, and societal units, such as cities. The reasons to adopt an IoT service can vary differently for each group. The adoption of IoT services has just emerged, therefore, only a few empirical cases have yet investigated this issue. Although these studies are not designed to examine their spatial dimensions, readers can still draw good insights from their results.

Individual/household level

Hsu and Lin (2016) did a survey of 489 IoT service users in Taiwan, and their results indicated that perceived usefulness and perceived enjoyment significantly affect the intention to adopt due to a perceived value of IoT services. Perceived privacy risk also plays a key factor in the decision-making. Kim et al. (2017) studied the adoption of smart home services in South Korea and found similar factors, such as perceived value and privacy risk. Mani and Chouk (2017) conducted a quantitative survey of 416 persons, both online and offline, and identified perceived uselessness, perceived price, intrusiveness, perceived novelty and self-efficacy as elements that affected consumer resistance to smart products. Similar to the first study, privacy concerns contributed to consumer resistance. Canhoto and Arp (2017) used a focus-group to study the early adopters of health and fitness wearables in Germany. Their findings suggested that the social context, such as peer pressure, seemed to play a significant role. Further still, institutional factors are also affecting the adoption of health apps. For instance, the German Government has launched a national incentive to promote healthy lifestyles, and there has been a rise in the number of health insurance providers and employers that offer financial incentives for using wearables.

To sum up, the perceived value/usefulness of the services and the privacy and security (perceived) concerns are the common impact factors for consumer-oriented IoT services adoption. Besides, institutional factors, such as government policy, organisational policy, and social context, e.g. peer pressure, can also play critical roles. All of these factors are hardly non-contextual factors. Their perceived value can vary by age, gender, and culture, which are spatially embedded. Privacy and security concerns also relate to government regulations and culture that will vary from one place to another.

Organisational/industry level

Fewer studies have been done on the industry level. Hsu and Yeh (2016) investigated the adoption of IoT technologies in the Taiwanese logistic industry and identified three critical factors: environment, organisation, and security. Environment includes government policy, supporting industries and competitive pressure. Organisation includes expected benefits, top management support, and organisational readiness. Security refers to data security, institution security, and system security. Among these, government policy is inherently place-dependent. Governance often reflects the policy and regulatory environment of information technologies. The public authorities can affect, limit, or push the diffusion of innovations by playing the role of service provider, the financier of basic research, consumer, and legislator (Windrum and García-Goñi, 2008). Supporting industry and competitive pressure relates to social and organisational context. Security issues can vary in their institutional and cultural contexts.

Societal level

This level of IoT adoption is under-researched. Even when the rise of IoT has not been studied extensively as the next step in the information society, some of the previous research on the spatial components of the information society can be a useful start. First, devices are the interfaces between the physical and the digital worlds as a computer, a smart phone, a smart watch, or a virtual reality headset. The usage, availability, and trends of these devices vary across locations (Wilson et al., 2013). Second, access to information technologies is not done just in the presence and absence of the infrastructure (Forman et al., 2005). The cognitive ability and the desire to access these digital services, their ownership and the cost/speed of their access are all factors that are affecting access. All these factors are also geographically embedded. The physical conditions of a location, such as its climate, topography, and geomorphology, are other potential factors. Third, culture can encourage or daunt a certain type of digital technology/service since that service is embedded in and contributes to the unique characteristics of a location. Schwanen and Kwan (2008) pointed out that the socio-physical context is influencing the usage of digital technologies in our daily lives. Previous research shows that cultural factors, such as language, ethnicity, and organisational culture, are related to the access and usage of information technologies (Jin and Liang, 2015; Welch and Feeney, 2014). Governance often reflects the policy and regulatory environment of information technologies (Wilson et al., 2013). Particularly, when developing public services, the involvement of the government and the public authorities is self-evident. Public motives indicate why a certain type of public service is needed in a certain place and thus are highly place-dependent. For instance, for the development of public IoT services, such as smart city and smart public transportation, a good understanding of public motives is crucial for successful implementation. Article 3 furthers this discussion on contextual factors during public IoT service implementation.

Various policy initiatives have listed a number of social benefits of adopting IoT (Council of the European Union, 2008; European Commission, 2016; MIIT (Ministry of Industry and Information Technology of the People's Republic of China), 2011; OECD, 2015; The Government Office for Science, 2014) that range from economic growth and industry competitiveness to addressing social challenges. The adoption of IoT is expected to provide solutions to these highly context-based societal problems. In addition to benefits, there are also challenges (Riggins and Wamba, 2015), such as what role will humans play in the IoT era? Can humans keep up with the technological changes? The dark side of adopting IoT technologies will likely be dealt with differently in different cultures and places.

The contextual factors for different levels of adopters are summarised in Table 7.

Table 7: A summary of different levels of adopters (Source: Author)

Different levels of adopters	IoT service characteristics (perceived value)	Perceived risks	Contextual factors
Individual/ Household	e.g., convenience, functional usefulness, fun, entertainment	e.g., privacy risk	Age, gender, access, cognitive abilities, peer pressure, and institutional, social and cultural contexts
Organisation/ Industry	e.g., productivity, cost reduction, developing new business models	e.g., data security, institution security and system security	Organisational/industry context, competitive pressure, and institutional, social and cultural contexts
Society (cities, regions, and nations)	e.g., sustainability, optimizing existing public services or providing new public services, addressing societal challenges	e.g., regulatory risk, protection of privacy and data security risks, systems security and social risks	Infrastructure and geographical conditions, governance, peer pressure, and institutional, social, and cultural contexts

3.6 PUBLIC POLICY AND INDUSTRY EMERGENCE

The rise of IoT is mainly a technology-industry driven phenomenon; however, the role of public policy through various policy initiatives is important to help facilitate the uptake of the IoT in society. This sub-section explores this institutional aspect, which affects the adoption of the IoT in society. Since the IoT industry is a type of new technologically based industry, I apply the path-creation approach to discuss the role of public policies in new technological-based industry emergence.

3.6.1. THE ROLE OF PUBLIC POLICIES IN PATH CREATION

Path creation is the emergence of new industrial development, which is a process of mindful deviation and co-creation by heterogeneous actors and networks (Garud and Karnøe, 2001). At the very core of this theory is the proposition that any new industry path does not emerge accidentally. It is widely recognised that path creation is non-linear because the emerging contingencies influence the learning processes (Karnøe and Garud, 2012). Thus, knowledge creation has become the centre of the debate. Evolutionary Economic Geography (EEG) and regional innovation studies (RIS) contribute to understanding this process as "evolutionary" and "place-dependent." The policy implication, therefore, is to formulate policies that are based on its related variety and Constructing Regional Advantages (Asheim et al., 2011).

EEG's conceptualisation regarding path creation began at the firm level, i.e., such a process is conditioned by a region's pre-existing industrial structure and the firms' technological relatedness (Frenken and Boschma, 2007; Martin, 2010; Neffke et al., 2011). "Evolutionary" highlights the process of increasing diversification, selection, and retention, especially considering the notion of related variety, i.e., the diversity of industries in a region that are cognitively related (Frenken and Boschma, 2007). In this regard, history matters, i.e., regions are more likely to diversify into technologically related areas. Policy can take on the role of fostering cross-sectoral connections for both the new and the established actors (Boschma, 2014).

EEG's firm-centric view has been criticised for downplaying the role of non-firm actors, such as institutions, and public policy that co-evolves with the firm-based organisational routines

(Coenen et al., 2016; Strambach, 2010). One strand of the literature responds by applying a regional innovation system (RIS) perspective. It emphasises that the path-creation process is "place-dependent." Regions can be differentiated by their knowledge bases: scientific analytical, engineering synthetic and artistic symbolic (Asheim et al., 2011), or by different innovation barriers (Tödtling and Trippl, 2005). Further, Martin and Martin (2016) pointed out that regions vary in their formal and governance capacities to support industrial path development.

Since each region has its own unique spatial settings, the path creation process is contingent not only on the related variety of the firms, but also the differentiation of its regional settings in its innovation systems (Asheim et al., 2011; Coenen et al., 2016). This view rejects the top-down approach, such as "one-size-fits-all" (thereby assuming that Research and Development policy can benefit every region) and "picking-the-winner" (selecting sectors and regions *a priori* as targets for policy-making) planning strategies. The top-down approach would fail, as it neglects the related variety and the unique embedded spatial settings of a region. The policy implication here is to construct regional advantages and facilitate differentiated learning and adaptation, for example, by using regional policy platforms (Cooke, 2007). The Constructing Regional Advantages concept has been adopted by policy-makers for the EU's innovation policies, for example, smart specialisation (Boschma, 2014).

Empirical studies point out that to only look at the precondition of a region and knowledge creation is not sufficient. Not only does the history matter, but how actors and networks understand where the future is heading matters as well. Steen (2016) studied the emerging of the Norwegian offshore wind industry and stressed the role of its agency's visions and expectations as a primary genitive mechanism for path creation. Governments can impact the consensus building of future visions by creating dialogue space (e.g., a hybrid forum) for multi-stakeholders to interact with each other (Dusyk, 2011). For path creation, knowledge is not the only resource distributed outside the regional boundary. Karnøe and Garud (2012) followed the formation of the Danish wind turbine cluster and concluded that path creation is accomplished through the co-creation of heterogeneous resources, such as international users, supply competencies, and regulation. Since the formation of these resources is not bounded within a single region or state, it is defined as extra-regional resources.

3.6.2 A RESOURCE-FORMATION VIEW OF PATH CREATION

The resource-formation view of early path creation is inspired by the Technology Innovation System perspective, which stresses the institutional alignment process undertaken by actors and networks during technological change (Suurs et al., 2010). Instead of setting a territorial boundary, this view follows the movement of actors, networks and institutions for technological development (Carlsson and Stankiewicz, 1991). Thus, the alignment process involves the movement of resources by both actors and networks through extra-regional linkages. Binz et al. (2016) incorporated the role of extra-regional linkages and defined early path creation as a process of critical resources alignment and anchoring. Anchoring extra-regional resources refers to the interactive process of actors' inducing those key resources that emerge from other regions of the global technological field. They specified four key resources, i.e., knowledge, markets, finance, and legitimacy and their formation process, i.e., knowledge creation, markets formation, investment mobilisation, and technology legitimacy (see Table 8).

Binz' et al. (2016) framework embraces the role of extra-regional linkages for key resources formation during regional path creation. However, they did not differentiate the role of governments and institutions from other types of actors and networks during the resource formation process. Article 4 goes a step forward to define the role of policies in new technological-based industry path creation.

Table 8: Key resources formation for path creation (Source: Binz et al., 2016:181)

Key Resources and Resource Formation Processes for Path Creation

Key Resource	Formation Process	Definition	Indicators
Knowledge	Knowledge creation	Activities that create new technological knowledge and related competencies (e.g., learning by searching, learning by doing; activities that lead to exchange of information among actors, learning by interacting, and learning by using in networks)	R&D projects, number of involved actors, number of workshops and conferences, activities of industry associations, linkages among key stakeholders, spatial dynamics in underlying knowledge networks
(Niche) markets	Market formation	Activities that contribute to the creation of protected space for the new technology, construction of new market segments	Number of niche markets, supportive tax regimes and regulations, subsidies
Financial investment	Investment mobilization	Activities related to the mobilization and allocation of basic financial inputs such as bank loans, venture capital or angel investment	Availability of financial capital and complementary assets for key actors, total sum of investment in companies in the field
Legitimacy	Technology legitimation	Activities that embed a new technology in existing institutional structures or adapt the institutional environment to the needs of the technology	Rise and growth of interest groups and their lobbying activities, institutional entrepreneurship by the actors in a new technological field

In conclusion, this chapter has analysed the relationship between IoT and context in two themes: 1) how does the adoption of IoT redefine context? And 2) how does context affect the production and adoption of IoT? Theme 1 concludes that the mass adoption of IoT technologies in society can redefine context, i.e. local/regional specialisations to the globalisation process. Automation and telematics re-organise the division of labour and the actor's networks by including non-humans as active actors in the network of knowledge production and interactions, especially for tacit knowledge. The rise of the IoT age has the potential to enhance the "context-based" specialisation of tasks in manufacturing and services. Theme 2 concludes that context can affect the production of IoT applications through various aspects in the spatial structure of knowledge and innovation networks. Regions and places can be test-beds for developing IoT applications. Knowledge-intensive activities are at the core of the activities that are taking place on a multi-level geographical scale, where local presence and international reach through contacts and clients are essential for knowledge transfer. The adoption of IoT services is affected by a range of social economic contexts in terms of adopters on different geographical levels.

CHAPTER 4: RESEARCH DESIGN

4.1 THE PHILOSOPHICAL AND METHODOLOGICAL FRAMEWORK

4.1.1 AN ONTOLOGICAL AND EPISTEMOLOGICAL PERSPECTIVE

How an inquiry is conducted reflects the author's philosophy of knowledge. The view regarding ontology and epistemology provides the philosophical and methodological framework for the choices of methods and the type of data sources. Ontology asks, "What is the reality?" It is the science of studying being. Epistemology asks, "How do we know the reality?" It is about the process of obtaining knowledge (Bhaskar, 2009; Crotty, 1998). Methodology is the theory of methods, which identifies the specific focuses or process of a set of methods (William and Turner, 2007). These chosen methods then become the practical tools to support the methodology, which contains the techniques then use collect and process the data from their sources (Patton, 2014).

A central question to ask as well is whether a reality can be perceived as objective (positivism) or subjective (relativism) (Bhaskar, 2009; Sayer, 2012). These two views address knowledge and truth in contrasting ways. Positivism asserts that the operation of a society is obliged to general laws (Bryman and Bell, 2015:15). Similar to the laws of physics, these laws are independent of any man's will. This philosophical branch searches truth based logical validity and falsification for the variables and concepts. Relativism, on the contrary, denies the universal existence of a truth. Instead, that truth is always relative to a certain point of view of the minds examining and the conditions of knowing. It also asserts that truth is socially and culturally constructed. Critical realism (Bhaskar and Hartwig, 2010) originated as a scientific alternative to these two extreme views of truth and reality.

Critical realism posits a comprehensive philosophical standpoint that is built on Bhaskar's work on transcendental realism (the general philosophy of science) and critical naturalism (Bhaskar, 1975, 1979, 1989, 2009; Bhaskar and Hartwig, 2010; Collier, 1994). Transcendental realism goes against Comtean positivism/hermeneutics and instead takes Bhaskar's transcendental positions on certain ontological and epistemological arguments (Bhaskar, 1975). Transcendental realism views things as what they are rather than how they appear to humans and sees the world as an open system (Sayer, 2012). Based on this view, the methodological implications of transcendental realism is posterior reasoning that uses postulated entities and analogies (Yeung, 1997). Critical naturalism argues that the transcendental realistic philosophy of science can be applied to both natural science and social science (Bhaskar, 1979). However, it also requires adaptation, since the human society is fundamentally different from the natural world. As human agency is produced by pre-existing social structures, and more importantly, humans are able to consciously reflect on and modify the actions that produce those structures. Indeed, the mechanisms of social events are much more complex than those of the physical world. A combination of transcendental realism and critical naturalism then became critical realism.

Critical realists claim that the world encompasses not only events, contexts, experiences, interpretations, and discourses, but also the underlying structures of power and changing forces, regardless of knowing based on human experience (Bhaskar, 1975, 2009). Critical realism thus rejects both empirical realism and transcendental idealism (Collier, 1994). It argues for a stratified ontology that is based on the open system view of the world and an *a posteriori* evaluation of knowledge (re)production. The world is structured, differentiated, and changing between three levels: the empirical (i.e., the experiences that people have through events), the actual (events that occur regardless of human experience and its knowledge of them), and the real (i.e., agents, structures and their causal power) (Sayer, 2012). A stratified reality of social science implies there is a pre-existence of social structures that can be transformed and reproduced by social actors and the continuous ongoing structuration that lies between structures and agency (Yeung, 1997). The realist ontology means that objects exist, regardless of human experience or its knowledge of them. It should be differentiated from the realist epistemology (*a posteriori*), which argues for the social knowledge of these experiences. The epistemological arguments demonstrate the internal and external relations between the real and the actual, which requires an immanent critique (i.e., contextualising the objects and their categories that both are inherently products of a historical process) (Bhaskar, 1979).

Critical realism, therefore, agrees that reality exists independently of our knowledge of it, so our ability to obtain the truth is limited. The aim of scientific inquiry is not to know reality with absolute certainty, but rather to try and understand and explain it even though we may never reach that reality in its ultimate form (Sayer, 2010, 2012). Different from the positivism thinking of truth as being fixed, unchangeable, and absolute, critical realism considers truth as being conditioned, and hence knowledge of truth is an accomplished production of those knowledgeable actors that exist in the social world (Pratt, 1995). Critical realism has received wide attention in the social sciences, including human geography, for a few decades. Its search for causations helps researchers explain social phenomena and suggest policy recommendations that can address social problems (Fletcher, 2017).

4.1.2 METHODOLOGICAL IMPLICATIONS

The methodological implications of critical realism can be understood in three ways. The first is the iterative abstraction of knowledge. For the purpose of scientific research, knowledge must be abstracted from its particular conditions. Abstraction is the first step toward conceptualising and theorising a social phenomenon (Sayer, 2012). Abstraction distinguishes external from internal relations between objects and events, so abstraction can be useful for identifying causal structures and generative mechanisms (Sayer, 1981). Iterative abstraction is embedded in retroduction. Retroduction entails a move from pure descriptions of a phenomenon to the abstraction of its possible causes (Bhaskar, 2009). Thus, abstraction follows an iterative method. It abstracts from the particular and then returns to the particular. According to Yeung (1997) there are two analytical criteria to review to determine whether an abstraction is realistic enough that a causal mechanism can be abstracted from it: First, when is this mechanism activated under appropriate circumstances or contingencies? Second, can this phenomenon be caused by other different mechanisms? Iterative abstraction tells us why we need to apply retroduction, but without providing us the process for how to do it in actual practice. Grounded theory can thus offer a valuable potential accompaniment to abstraction.

Grounded theory can be used to reinforce iterative abstraction. It mediates the theory and the practice, so that abstraction derives from concrete empirical observations. Grounded theory provides a systematic qualitative methodology to use to construct theory through data analysis (Martin and Turner, 1986). Different from the hypothesis-deductive approach, grounded theory follows the inductive question/data- coding - category - theory sequence (Strauss and Corbin, 1994). As more data are collected and reviewed, certain ideas and concepts can be extracted via codes, while codes are then grouped into categories; hence new theories can be built based on these categories (Glaser, 1992).

In practice, due to the lack of any ontological attributes of reality, pure inductive grounded theory methodology may simply end up as another form of empiricism. A critical realism approach then connects this method with iterative abstraction. Thus, the theorising process is neither purely deductive, nor is it purely inductive, but rather, its intent is "to achieve a harmonious synchronisation between deductive abstraction and inductive grounding of generative mechanisms" (Yeung, 1997:63). Since a critical realism approach is neither inductive nor deductive, but rather a kind of dialectic of both, and it is neutral on the choice of a quantitative/qualitative approach. Even though qualitative methods are useful to abstract causal mechanisms by exploring subjects' understandings and interactions of a concrete phenomenon, it cannot be directly applied to explain the reality without a careful check into all contingencies. At the same time, quantitative methods can inform on the abstraction of causal mechanisms by revealing the empirical regularities between objects; however, these statistical generalisations are contingent generalisations that can only work in a specific temporal-spatial context (Sayer, 2012; Yeung, 1997).

The third critical issue related to credibility and validity concerns a triangulation approach (Denzin, 2012). Triangulation indicates a multi-method approach, and according to Denzin (2017), it offers four ways of accomplishing it: (1) data triangulation with respect to time, place, persons, and levels; (2) Investigator triangulation via multiple observers of the same phenomenon; (3) Theoretical triangulation via multiple theoretical perspectives regarding the interpretation of the phenomenon; and (4) Methodological triangulation that involves using more than one method to gather the data, i.e., interviews, observations, questionnaires, and documents. This triangulation method contributes to the validity and reliability of both data collection and transformation. The application of triangulation is examined carefully in Section 4.5.

4.2 RESEARCH METHOD

4.2.1 A QUALITATIVE CASE STUDY-FOCUSED RESEARCH METHOD

Various theoretical and practical factors can affect the choice of research method. For this dissertation effort, the characteristics of the research topic significantly influenced the formulation of the research questions, and hence the choice of the research methods. IoT is a timely topic, but that feature is a double sword. On the one hand, a timely topic provides great freedom on the choice of methods. On the other hand, a timely topic means there is already relative lack of previous research/empirical evidence. In order to cope with this challenge, I used the qualitative case study method. There are two arguments for making that decision. The first is the nature of the research questions. The second is the relative lack of ready-made empirical data.

The nature of the research questions can be both explorative and explanative. Since the emergence of the IoT is so recent, there has been a lack of previous research on its applications on various societal contexts. This study is, therefore, more about theory generalisation and not statistical generalisations. As a result, the research questions that were designed were explorative "HOW" types of questions on two themes: 1) *how does the adoption of IoT redefine context?* 2) *How does* *context affect the production and adoption of IoT?* Often a case study method is preferred when "how" or "why" type of questions is being raised, especially when exploring new topics in a research field (Yin, 2013).

Under Theme 2 are three questions: *RQ3: In what way does place matter for the production of IoT applications? RQ4: In what way does place matter for the adoption of IoT services? RQ5: In what way do public polices facilitate the emergence of the IoT industry?* These questions investigate the IoT phenomenon as a contemporary social event that occurs in complex social structures and relationships. The investigator has no control over the actual behavioural events. This "incorporation of context" nature of the research questions, therefore, suggests the case study method. In comparison with surveys and experiments, case studies are particularly useful for examining contemporary phenomenon (as opposed to historical ones) within a real-life context when the boundaries between the phenomenon and its context are not yet obviously evident (Yin, 2013). The case study method can capture the richness and complexity found in historical and contextual conditions, which then enables the researcher to draw conclusions regarding certain qualitative changes in specific spatial-temporal settings (Ragin, 1987).

However, Theme 1 was theorised differently here due to unpredictable practical constraints. Theme 1 presented two questions: *RQ1: How does IoT redefine knowledge production/interaction and enable innovation?* And *RQ2: What are the spatial characteristics and consequences of adopting IoT?* Ideally, this investigation should be conducted when IoT has already reached mass adoption, because these two questions are mainly about the causal relationship between the adoption of IoT and its spatial consequences. Applying the critical realism approach of being *a posteriori*, researchers can hardly draw any realistic conclusions about future events. In practice, it was impossible to predict exactly when the emergence of IoT would lead to mass adoption. By the end of this research project, however, the IoT had not yet reached mainstream adoption. The theorisation and discussion of this theme, therefore, remained focused on a literature review and theory development with just a few actual empirical evidences of adopting IoT.

This relative lack of ready-made empirical data thus set limitations on the choice of research methods. To the best of my knowledge, the publication of academic studies on the adoption of IoT services has only appeared since 2016 (e.g., marketing research efforts).the first firm- level database of the IoT industry was established by a German- based technical consulting company only in 2015. By then, I had already made all case choices. When I started the research in 2011, however, I needed to collect first-hand data by myself. Under such conditions and considering the nature of my research questions, a qualitative case study orientation and approach was the most suitable choice. The method fits the research resources, which were in their detail only relatively small samples with multiple causations (Patton, 2014).

4.2.2 Reflections of the method

First is the issue of generalizability. Generalizability refers to the external validity of a study. It deals with the ability of extending the validity of one case study and its conclusions to other cases of a similar kind (Mills et al., 2010). Strategies that support claims for generalizability very much depend on the ontological assumptions. A realist ontological assumption presupposes the existence of reality, and so the case study method is a preferred manner to use to access this underlying reality and let researchers verify and assess the generalizability of the findings to a specified population (Strauss and Corbin, 1990; Yin, 2013).

Researchers may be unable to assess the causal mechanisms from the idiosyncratic behaviour of a particular case (Eisenhardt, 1989). Given the richness and depth of these data, there is a temptation to build a theory that lacks simplicity in its overall perspective. However, much can be learned from a particular case because the general view is an aggregative abstraction of many particulars. Since human events always occur in social contexts, one can hardly argue that context-dependent knowledge is less valuable.

Subjectivism is a person's experience, perception, and interpretations of the world as well as the material conditions and social relations that shape that person's vision. Researchers who are critical to the case study method always point to the fact that more subjective judgments are used to collect data (Yin, 2013:41). The study thus contains the observations and perceptions of the investigator. Subjectivity, however, can be viewed as a source of strength and reflexivity, which then contributes to the grounding of theories (Demirdirek, 2012). A case study often contains a substantial amount of narrative that approaches the complexities and contradictions found in human affairs. It is not easy to theorise or formulate this rich real life ambiguity into neat propositions. However, this difficulty is not due to the case study as a method *per se*; rather it is due to the inherent characteristics of reality.

4.3 THE CHOICE OF CASES

4.3.1 PURPOSIVE NON-PROBABILITY SAMPLING

I used purposive non-probability sampling as a strategy to select my cases. Instead of inferring to the general population in statistical terms, the purposive non-probability strategy was to ground the theories based on "analytical generalisation" and thus generalise a particular set of results to the broader theory until theoretical saturation was reached (Strauss and Corbin, 1990; Yin, 2013:43). Thus, the choice became not representative of the population, but instead based on the case characteristics because these characteristics were of particular interest to the researchers. Since researchers make the choice that they believe is most appropriate, this strategy has a tendency to be subjective. Nevertheless, it provides an opening for new research topics when there are only limited numbers of people who have the necessary expertise for the study (Bryman and Bell, 2015:190).

Palinkas et al. (2015) suggested a few strategies to use to implement purposeful sampling. *Typical case* describes and illustrates what aspects are typical to those unfamiliar with the setting, not make generalised statements about the experiences of all participants (Patton, 2014). *Snowball* identifies cases using the snowball effect of respondents introducing other people who have similar characteristics, and so on. *Critical case* represents the logical generalisation of information. If it is true in this one case, then it's likely to be true in all other cases. *Theory-based* finds manifestations of a theoretical construct to elaborate and examine the construct and its variations. *Convenience* collects information from participants who are easily accessible to the researcher. *Opportunistic or emergent* refers to taking advantage of circumstances, events, and opportunities for additional data collection as they arise. Some of these can also help the researcher reduce undue subjectivity.

4.3.2 CRITERIA FOR MAKING THE CHOICE

The criteria for the choice of cases are based on two major concerns and, most importantly, timing. As was mentioned in the introduction section, the time sequence was crucial for the development of each article. From 2011 to 2017, I followed a vision - development – as an adoption timeline to arrange the articles. The empirical context for developing Article 1 was fundamentally different from that for Article 3. The second factor was availability. I was describing the IoT phenomenon during its early formation phase. The choice of cases was thus constrained by a high degree of information asymmetry and the scarcity of public knowledge resources. Under such a situation, I developed two criteria to use:

First, were the characteristics of the case of interest to my research question(s)?

Second, could I get access to the case? If I could get that access, did I have the skills, resources and capabilities to carry out the study appropriately?

4.3.3 CASES

Case 1: The creation of the first IoT pilot city Wuxi in China (data were collected between 2011 and 2012, for Article 1)

Case 1 is of interest to RQ5: In what way do public polices facilitate the emergence of the IoT industry? When I started this dissertation project at the end of 2011, IoT had already emerged as a national/supranational strategy in the leading economies across the globe. However, of these government initiatives, the central government of China and the municipal government of Wuxi have taken the boldest actions to set up the world's first IoT pilot city. During my visit to Wuxi in 2012, the local government there even used the notion of a "*policy to create the market*" to promote the IoT industry. This notion was, of course, an exaggeration. Yet it showed an exceedingly high level of government commitment to the creation of an industry that was about to display strong signs of is future potential.

In 2012, no place in the world was more dynamic and eventful for IoT emergence than the city of Wuxi in China. Besides, with my Chinese background and language abilities, the Wuxi case was undoubtedly the best choice. The Ministry of Industry and Information Technology (MIIT) had just launched China's Development Program of IoT in its 12th Five Year Plan and anchored IoT as one of the most important strategic high grounds for the world's next economic and technical development trends. ¥ 5 billion direct national funding was mobilised for 149 IoT enterprises. The development plan of the 2020 Wuxi National Sensor Network Innovation Demonstration Zone received approval from the State Council. By mid-2012 over 600 IoT companies of annual sales volume over ¥ 1 million had located into the Demonstration Zone. By the end of 2012, the newly established national IoT Centre (located in Wuxi) had also expanded its platform to 13 research institutes, 10 universities, 4 investment companies and other local members from both the public and private sectors. It had incubated over 10 start-ups in the IoT field.

The limitations of this case study were obvious. The case is unique in its temporal-spatial intersections. The emergence of the IoT pilot city, Wuxi, was highly embedded in its institutional and geographical settings, and thus, was non-replicable. The purpose of the case study was not to generalise a "best practice", but rather to explore the contextual factors that can affect the emergence of the IoT industry, including policy initiatives.

Case 2: Six green IoT projects all coordinated in the Gothenburg region (data were collected in 2013, Article 2).

Case 2 relates to RQ3: In which way does place matter for the development of IoT applications? This case initiated in the spring of 2013 when many of the IoT research projects had started to come out of the laboratory and test the market. The idea was to write about the commercialisation of the IoT technologies in industry. While studying the various IoT policy initiatives for the first article, I learned that IoT was identified as an important driver for sustainable development. Since I was based in Gothenburg, a natural choice was to check what was happening in this city. I did some research on the Internet, and by checking with my Gothenburg friends, I learned about some of the ongoing Green IoT projects in the city. I began with two projects and then through the interviewees' knowledge expanded those contacts. In the end, I collected six ongoing Green IoT cases.

The disadvantage was the limited number of these cases. However, they were in the right combination of variety for the sectors, industries, development phases, and application markets. There were certainly better projects running in some other corner of the world, but these were the best cases I could gain access to by using the resources and knowledge that I had in 2013. I then developed an analytical framework based on literature review before applying the case discussions. The purpose was not to ground patterns from the cases, but rather to use the case studies for theory development.

Case 3: Smart public bike sharing schemes (data were collected between 2014 and 2016, for Article 3)

Case 3 relates to RQ4: In which way does place matter for the adoption of IoT services? The case concept was developed after my mid-term seminar at the end of 2013 when I received feedback that suggested that a case study of everyday life implementation of IoT would be desirable. As a result, I turned my search to the most widely spread IoT service at that time–smart public bike sharing schemes. By April of 2013, there were an estimated 535 schemes with 517,000 bicycles in 49 countries. Since I wanted to investigate the contextual factors during the adoption phase in the host city, two preconditions became important. The first precondition was my understanding of the place, such as the pre-existing structure and its relationships to the public transportation system and the citizens' needs. The second was the quality of the interviewees. For these two considerations, I decided to study the scheme in Gothenburg (where I live) and in Hangzhou (a city that I know well and where I had good personal contacts in the transportation sector). I did two rounds of interviews in 2014 and 2016, so the case study reflects not only the implementation, but also the evolution of the chosen schemes.

The weakness was the limited numbers of the cases. How much can two cities represent more than 500 smart public bike-sharing schemes? How much can the smart public bike sharing scheme represent a large number of various IoT services? To counterbalance this idiosyncratic problem, I applied critical case and theory-based strategies. Based on a literature review, I then developed an analytical model to ground the theories from the critical cases. In this way, I showed that if these contextual factors could affect the selected cities, they might affect other cities as well. If these factors were affecting the adoption of this public IoT services, they might also affect the adoption of other types too. However, the result was limited to public IoT services and not applicable for the adoption of private individual or household IoT services. For this latter group, I undertook supplementary discussions in Kappa 3.5.2 based on my academic findings from the current studies.

Case 4: The evolution of EU IoT policy-making (data were collected between 2012 and 2017, for Article 4)

Case 4 relates to RQ5: In what way do public polices facilitate the emergence of the IoT industry? It began in 2012 during the writing of the first article. The project initiated with a genuine interest in studying the role of the government and public policies in the emergence of the IoT industry. I wrote first about the Wuxi IoT pilot city in China when many milestone events were happening there. At the same time, the EU case attracted my attention. Different from the Chinese approach, the EU was taking serious consideration in becoming a regulator of the IoT emergence. It was the first to anchor the IoT as a policy area worldwide, indeed almost half decade ahead of its most technologically advanced Member States. Between 2010 and 2012, the EU pioneered the debate on the necessity of an intergovernmental IoT governance structure that could be independent of the existing Internet governance structure.

The scope of these debates was beyond today's discussion on data security and the protection of privacy; rather, it went deeply to the technological ethics concerning the fundamental principles for such a relationship between people and machine intelligence. For many reasons, this governance issue was suspended at the end of 2012. One explanation could be that the time was not yet ripe. Nevertheless, the EU case was still interesting in following up due to its special institutional settings and the interactions between its Member States and the EU.

The weakness of this case is the spatial setting. One can easily argue that the supranational level is less spatial than the national or regional level. The spatiality in this case was more reflective of the interactions between the supranational level and the Member States. Could I have used another alternative than the EU case? Sometime around 2015, many Member States started to launch national IoT strategies and financial instruments. This would be an interesting case for investigating the policy responses in different countries. If I had started my project in 2015, it would have been a promising alternative. My study on the EU level may serve as a precondition, however, and be useful for future studies at the EU Member States level.

4.4 Data sources and data collection

Qualitative case studies typically combine multiple data collection methods; interviews, observations, archival records and documentations are particularly common (Eisenhardt, 1989). The data sources used in this dissertation were mainly interviews, site visits, and documentary sources. A variety of data resources are considered useful for the quality of case studies. The strategy of using a combination of data sources will increase the validity of a study through the use of triangulation (Denzin, 2012).

4.4.1 Interviews

Interviews are a common interactive method used for gathering data when conducting systematic inquiry. For instance, close dialogue is a proven research instrument for industry analysis in economic geography, especially for geographers to study the complex reality of the economic world (Clark, 1998). Close dialogue strategy is more valid in understanding the actual practice of decision-making by social actors (Yeung, 2003). In my case, due to the lack of reliable public data during the early formation of the IoT industry, interviews became the most important data source for the research project. Also, I have a background from the industry. Back to the early 2010s, I was an industry analyst at a mobile telecommunication cluster in southern Sweden, where I learnt the concept of IoT. At that time, the IoT vision has just emerged and I accumulated initial knowledge and contacts with the IoT industry through interacting with the companies in that cluster. Researchers can use interviews to acquire a large amount and variety of data in a relative short period of time with a good balance of depth and breadth. Notwithstanding these many advantages, critiques can relate to validity issues such as cultural differences and the power balance between the investigators and the interviewees (Barlow, 2012).

A total 40 formal interviews were conducted from 2012 to 2017. All interviews are individual-based. Most were undertaken face-to-face (34) and a few via the telephone (6). The average length was 45 minutes to one hour. The primary consideration when choosing the interviewees was the relevance of their knowledge, experience, and expertise related to the case being studied. Meanwhile, a balance of their professional background was also taken into account, including academia, industry, institutions and government in both the private and public sectors. In this way, I was able to obtain a coherent view of the case in terms of both depth and breadth, while also increasing the validity through person triangulation. In order to reduce any power unbalance, I always pre-communicated with the interviewees about my background, the purpose and use of the study, as well as a preliminary list of interview questions.

I conducted semi-structured interviews. Semi-structured interviews lie between the continuum of structured interviews and un-structured interviews. They are commonly used to address a number of pre-designed questions, but the interview questions are not totally restricted within that plan. It is presumed that some questions will evolve as the interview progresses. It is most effective when the investigator has some knowledge of the subject area but wants to expand the understanding of it through gathering the interviewees' unique experiences (Barlow, 2012). When conducting the semi-structured interviews, I always started with a list of questions and topic areas based on my acquired knowledge and the purpose of the study. For each interview, I re-formulated the questions or made different priorities for the topics based on that interviewee's background and expertise. During the interview, I began with the planned questions and then added new questions when opportunities occurred during the conversation. Often the interviewees would talk in more details about their own experiences and views if the investigator showed enough encouragement and an open and equal attitude.

Case 1 (in Article 1) is the emergence of the first IoT pilot city Wuxi in China. The purpose was to describe the story of Wuxi. I planned my interview questions for mainly four areas:

1. When and how did Wuxi become the first IoT pilot city?
2. What was the policy and institutional background of this emergence?
3. What was the industry background of the emergence?
4. Were there any obstacles to the emergence (personal opinion).

Case 2 (in Article 2) is a multiple case study of six ongoing Green IoT projects coordinated in the Gothenburg region. Since the purpose was to investigate the intermediary roles of KIBS, the focus was on the different actors and their interactions with each project. Interviewees were mainly the project leader who had the best knowledge of these aspects. The interview questions were arranged so as to address three aspects:

1. Identifying the KIBS' functions to facilitate the development from IoT technologies to Green services.
2. Describing the development, actors, and relationships of the project during all three phases: Initiating, development, and evaluation/knowledge dissemination (if the project experienced all three phases).
3. Suggestions for other Green IoT projects.

Case 3 (in Article 3) is a study of the implementation and service development of smart public bike sharing schemes in two cities (Hangzhou, China, and Gothenburg, Sweden). The purpose is to learn the factors that caused and then affected the adoption of this public IoT service in the hosting cities. I interviewed the project managers and the operators in each city in two rounds - the first time in 2014 and the second time in 2016. By doing so, I could trace the changes that had occurred during the actual implementation.

In the first round of interviews, the questions were structured according to the scheme framework provided by the handbook on Optimising Bike Sharing in European Cities. The interview questions were, therefore, structured into four parts:

1. The aims and objectives of the scheme.
2. The physical and technology of the scheme.
3. The governance structure of the scheme (who was involved, what were the roles and responsibilities of each actor, and how did the actors work with each other?)
4. The policy designs for the scheme (if any, at the city, regional, and national levels)

The second round of interviews was designed to update the development of the schemes and the evolution of the service characteristics. Additionally, since the EU data protection law was just coming into force in 2016, a question about its impacts on the ownership and management of data was added.

Case 4 (in Article 4) studies the evolution of the EU's IoT policy-making during the last decade. Is purpose was to understand the role of public policies in facilitating the emergence of the IoT industry in Europe. I interviewed mainly policy-makers and civil servants involved in the policy-making process in the EU, as well as people from the industry and institutions also involved during the process (e.g., through international cooperation or expert groups). The questions on policy-making were mainly on the following five areas:

1. The legitimacy of public policy intervention.
2. The learning and adaptation of the IoT policy priorities (2005 – 2017).
3. Research and innovation initiatives.
4. The interactions between the supra-national EU IoT policy when coordinating with member states or regions.
5. International cooperation.

4.4.2 SITE VISITS

Site visits is a type of direct observation that contributes to the positive development of a strong case study. As a source of evidence, it provides an opportunity for researchers to observe what is happening in the social setting directly, interact with the participants, and participate in activities (Pauly, 2012). I applied site visits to get a better understanding of the place where my case study was located. I did not directly use information gathered from the site visits in my case analysis; rather, the site visits provided me with good background information to better prepare the interview questions. During the site visits, I gathered some institutional reports and books for second-hand information resource material for my study.

A practical purpose of these site visits was also to get to know more potential interviewees than planned. Often, that made it much easier to arrange additional interviews with the interviewee's colleagues or people with nearby organisations when the investigator was onsite.

Site visits were mainly used for Case 1, Case 3 and Case 4. For Case 1, I visited the 2nd Expo of the Internet of Things Technology and Application in Suzhou, China (April 2012). The purpose was to gain the latest insights into the IoT applications and service offerings, meet many IoT practitioners working on the frontlines, and listen to their thoughts on the development of this emerging industry. During the same timeframe, I also visited the National IoT R&D Centre in Wuxi, China. I expected to be conducting interviews there, so I also took a walk around the whole area to get a general impression of the place, the organisations there, and the surrounding companies. In October of 2012, I went to the 3rd International IoT conference hosted by Wuxi. There, I was able to meet and converse with researchers, industry representatives, and policy-makers involved in the emerging IoT community from around the world. Some of them became my interviewees later. These site visits provided me with insightful and contextual knowledge about my case studies. Since this knowledge was much comprehensive and broader than the information that I gained from the actual interviews, they helped me reduce bias during my later interpretation of the information I acquired during the interviews.

For Case 3, I visited Hangzhou during the spring of 2014 to conduct interviews and get more interview opportunities, as well as try the smart public bike sharing service. Since I live in Gothenburg, I did not need to do a similar site visit for the Gothenburg scheme. I was familiar with the city Hangzhou through previous experience, but I had never tried the public bike sharing service there. My own experience using the service helped me design better interview questions and reduce bias when processing the information from the interviews later.

For Case 4, I attended the 2014 IoT Week being held in London. I went there primarily to conduct interviews. Since the IoT week was organised by the European Commission as a main avenue and instrument to coordinate projects and various work packages, I gained a clear understanding of the policy areas, priorities, and current debates on related EU IoT policy-making issues by participating in the conference sessions. The people I met and talked with their provided unique insights for my overall understanding and knowledge of the IoT industry and my research.

4.4.3 DOCUMENTARY SOURCES

Documentation provides researchers with contextualised, naturally occurring evidence when direct observation cannot be undertaken or needs to be supplemented (Raptis, 2012). These sources can be written, audio, and/or visual artefacts. To make good use of documentary sources, researchers should be well aware of their authenticity and credibility. Factors like who created the document and when, where, and for which purposes may affect the credibility of the documentation, and thus require cautious assessment.

For this dissertation, I used documentations as second- hand evidence to supplement and triangulate the interview materials. These sources included policy documents, consultancy and company reports as well as websites and organisation- issued materials.

Policy documents included national IoT strategies from the major nations and institutions like the EU, US, China, Japan, and South Korea and institutional reports about IoT issues, such as OECD, the US National Intelligence Council, the China Academy of Telecommunication Research, and European Commission studies. These documents were used to get an overview of various policy initiatives regarding the uptake of IoT emergence. Policy initiatives were impossible to obtain from direct observation, nor could they be provided systematically from interview conversations, but these materials did offer comprehensive policy background on the cases and supplemented rich contextual evidence to bolster the facts I gained from the interviews. Case 4 provided a holistic picture of the EU IoT policy-making during the last decade, so I extensively used various types of policy documents at the EU level. These ranged from the Treaty, Charter of Fundamental Rights, to the Commission Communications, Council Conclusion, memos, and staff working papers created during different policy-making periods. The purpose of using multiple documentary sources from different time periods was not just for replication, but rather to illustrate the changes occurring and make connections so that the different facets of a concrete phenomenon could be researched. Such data triangulation can helped reduce bias both from the interviewees and interpretation of the data by the investigator.

Consultancy and company reports can also be used as a complementary data source. Since the emergence of the IoT is so recent, there has been relatively less academic or institutional evidence available to researchers. Company reports are a direct source of the current industry dynamics in the field. Consultancy firms, due to their strategic position in the business world and the close interactions with their clients, have the advantage of being able to produce timely studies about the most recent industry insights. At the same time, I was fully aware of such problems as credibility and bias. Due to different interests, the rationale underlying the consultancy reports might not fit the purpose of my research. I, therefore, selected these carefully and interpreted their conclusions with a critical stance. The company reports came mainly from the leading firms in the IoT industry, such as Ericsson and Cisco. Although their statements were likely biased, they are part of the industry dynamics and indeed influential for IoT development.

Websites were an important source of information collection for all the cases. I used websites as portals to gather background information about the organisations, projects, and the interviewees. The purpose was to form a number of distinct categories before designing the interview questions. The information thus provided an empirical background to utilise during my discussions with the interviewees. Besides, websites also could provide a range of web-based databases. For example, in Case 4, I used the EU Cordis database to analyse the Member States involvement in EU- funded IoT research and innovation projects.

4.5 Discussion of validity and reliability

A critical realist methodology of iterative abstraction, grounded theory, and triangulation was applied to enhance the rigor of this study. This sub-section focuses on two foundational elements -- validity and reliability. Validity relates to quality control and is largely concerned with whether the claims, implications, and conclusions of a study can be justifiably made (Yue, 2012). Reliability assesses the extent to which the results and conclusions drawn from a case study can likely be reproduced if the research were conducted again (Ward and Street, 2012). Triangulation is a common technique used to reduce bias and improve both validity and reliability by using multiple sources of evidence (Cox and Hassard, 2010; Ward and Street, 2012).

A validity problem is related to how to catch the "moving target". The ontological and epistemological assumptions of critical realism provide both philosophical possibilities and methodological ways to address the problem. This thesis project follows the emergence of the IoT in real time, which is a fast changing phenomenon that is not following a predicable path. In this case, how does one theorise such a "moving target"? The critical realism approach inspired my work on the possibilities and ways to conduct scientific research on this type of social phenomenon. A realist approach sets the conception of social science as explanatory (searching for mechanisms) rather than predictive (Bhaskar, 2009). This view provides a philosophical possibility for how to theorise the "moving target" of the IoT, that is, not to predict, but rather to understand the underlying causal mechanisms in the explanations. Iterative abstraction and grounded theory provided me with methodological guidelines to practice catching the "moving target". Since this realist epistemology is mostly *a posteriori*, the realisation of casual mechanisms are thereby contextually embedded and historically rooted.

Different triangulations were applied to strengthen the reliability of the study, and also to address the external validity of the results.

Data triangulation is when data are collected at different times or from different sources. As discussed in Section 4.4, the data for these case studies come from a variety of sources, including interviews, documentary sources, and websites. I used data from different sources to triangulate the same studied phenomenon. For instance, in Case 4, I used the EU Cordis database to analyse the national distribution of funding receivers for IoT research and innovation projects. The result showed there was a clear divide between the technologically strong and the technologically weak Member States: the technologically strong Member states were the major fund receivers. Such distribution contradicted the policy intentions of having inclusive development for all Member States. I critically reflect on this "crash" of evidence in the discussion section in Article 4.

Since the primary data of this study was mainly from interviews, I applied a more techniques to enhance reliability. For Case 1 and Case 4, the choices of interviewees were made from a mixture of professional backgrounds that ranged from institutions, government agencies to industry and academia. For Case 2, I used multiple cases from the same region to address the same research question, namely, does place still matter for the development of IoT applications? These cases came from different technology development periods and both private and public uses. In this way, I could reduce the bias from a single case. Interviewing the same person or the same project in different periods of time was also a practice used for Cases 3 and 4. Likewise, I reduced bias again by tracing both the change and the continuity of the same IoT projects. The characteristics of adopting IoT technologies differed on different geographical levels. Thus, the dissertation was designed as a multilevel study that ranged in its focus from local to global. Article 3 addresses the micro project level of a public IoT service adoption, while Article 4 looks at policy evolvement on the macro supranational level.

Investigator triangulation refers to the involvement of different researchers or evaluators in the same phenomenon. Article 2 was co-authored with an economic geographer and since the article was part of a bigger research project on Green Economy and Service Research, I could triangulate the theoretical development and case analysis with other investigators with the same intellectual perspective. All articles were presented in internal and external workshops and conferences related to service research, innovation studies, and European economic and policy studies. I also combined insightful comments from scholars from similar and related research fields. Further still, all published articles went through the peer-review process, which is a common quality that ensures the appropriate mechanisms are being used for scientific research articles. I received both constructive and thorough comments from the reviewers, all of which greatly improved the quality of my studies.

Methodological triangulation indicates that multiple methods of data collection are being used. The methodological implication of iterative abstraction and grounded theory abstracts causal structures and generative mechanisms through constant reflection and retroduction (e.g., immanent critiques). When I began this project in the autumn of 2011, the IoT was still a technological vision. During the project, the industry rapidly emerged across both horizontal and vertical sectors. Given that situation, a direct "jump in" to the phenomenon could lead to chaotic abstraction of its causal mechanisms. That is why I needed to undertake a review of the research filed its problematisation and theoretical background in order to abstract precise information on structural context and contingencies that I might not have been able to obtain directly from the empirical data.

I also divided the research questions into two main themes on the reflexive relationship of IoT and its context, to avoid ending up with a complex map of empirical conclusions that were only loosely connected. With this theoretical abstraction in mind, I went back to the phenomenon and contextualised the empirical cases for their different development phases and societal levels. In the end, I integrated and theorised the overall findings again in the kappa. This process, however, required constant updates and reflections about what had been abstracted and what was still evolving in the social construction of the IoT. My work remains a constant play between the empirical observations (case studies) and the theorising (abstraction) thus becoming a mixed-inductive and deductive approach.

Theoretical triangulation uses different theories to interpret data. The spatial characteristics of the IoT are not a stand-alone economic geography issue, but rather they can be analysed in their various literature strands. IoT is a phenomenon where local meets the global, and digital integrates with the physical world. Thus, I used the economic-geographic concept of context and knowledge as the entry point, then triangulated theories from the economic geography and innovation studies (local-global dimension), the information society literature (digital-physical dimension), and the KIBS literature gathered from both the service and innovation research fields (a multilevel dimension). To reduce bias, I applied two or more literature strands to develop the analytical framework for addressing each research question. For example, I applied all strands of the literature to address *RQ 2: What are the spatial characteristics and consequences of adopting the IoT?* The theories on KIBS functions and the Green perspective in economic geography were then applied to formulate the analytical framework used to discuss *RQ 3: In which way does place matter for the development of the IoT applications?*

To conclude, the validity and reliability of the thesis was clearly addressed by applying various triangulations and a combination of iterative abstraction and grounded theory within the realist methodological approach. These techniques enhanced the accuracy of the analysis as well as the explanation during the abstraction, data grounding and article development processes of the research effort.

Chapter 5: Conclusions and Outlook

5.1 Conclusions

The vision of IoT is to connect *anything* from *anywhere* at *any time*. It makes IoT the most popular technology in development today. On the contrary, a successful realisation of IoT is not about linking anything at any place, but rather to connect *something* at *some place(s)* for *potential users*. Networks of things, places and people are always spatially embedded. It is, therefore, not the spaceless sentiments of IoT, but rather these spatially embedded mechanisms create actual values that can turn this technological trend into reality. A car does not need to know how to drive, unless autonomous driving is a valuable service to its users. A sound understanding of spatially embedded mechanisms underlying the connected things, therefore, unlocks their potentials in both the value creation of technology and its adoption by society.

The spatial characteristics of IoT pivot on the relationship between IoT and its context. This thesis explores these spatial characteristics of IoT using two themes:

1) How does the adoption of IoT redefine context?

2) How does context affect the production and adoption of IoT?

Since IoT development is a knowledge-intensive innovation activity, this thesis constructs an economic-geographic theory of IoT using the geography of contexts and knowledge as an entry point. Based on this idea, the thesis proposes an integrated spatial framework to theorise IoT in terms of three dimensions: The digital-physical (i.e. the geography of information); the local-global (i.e. the geography of knowledge and innovation); and the multilevel knowledge dynamics (i.e. the geography of knowledge-intensive services).

Theme 1 concludes that the mass adoption of IoT technologies in society redefines context through automation and telematics. Automation and telematics enable an IoT network to become a producer and carrier of knowledge, especially tacit knowledge. Thus, IoT redefines the relational conceptualisation of distance by adding two types of proximity, namely *information network proximity* (infrastructure connectivity) and *information system proximity* (interoperability connectivity). Combining the digital-physical dimension with the local-global dimension allows for theorising the *contextuality of relevance and connectivity* to describe the spatial characteristics of adopting IoT technologies (Figure 8 shows an illustration of contextuality). Relevance and connectivity together explain the key elements needed for the value creation of IoT deployment. As for the spatial consequences of adopting IoT, the rise of the IoT age has the potential to enhance the "context-based" specialisation of tasks over functions.

Theme 1 consists of two research questions:

RQ1: How does IoT redefine knowledge production/interaction and enable innovation?

The adoption of IoT redefines knowledge production/interaction by being a producer and a carrier of knowledge, especially tacit knowledge. IoT thereby complements the role of humans in knowledge creation and dissemination, but in a way that is different from how humans do it. Humans produce tacit knowledge by experiencing and sensing (Gertler, 2003). Individuals disseminate tacit knowledge through personal demonstration and learning by doing. The interaction and dissemination of tacit knowledge between humans can be affected by geographical proximity and various geographically related proximities. For instance, in the local-global dimension (e.g. the geography of innovation theory), local buzz and the global pipeline are used to describe the spatial patterns of knowledge-intensive activities.

An IoT system creates and transmits tacit knowledge in a different way. IoT technologies can enable the production and acquiring of tacit knowledge via programming, sensor technologies and machine learning. Producing tacit knowledge is just one aspect of how IoT enables innovation. Once tacit knowledge is produced, it can be immediately disseminated through algorithms and software in the IoT networks, without having to demonstrate and practice that knowledge on one "thing" and then another. Thus, offering smart services via automation and telematics is the second aspect of how IoT enables innovation. However, there are also spatial constraints for IoT systems to be able to transmit knowledge, e.g., information network proximity and information system proximity. These spatial constraints relate to the second research question.

IoT enables innovation by (1) enlarging the knowledge producer and carrier from merely human-centred to a human-nonhuman network and 2) offering smart services that are realised by telematics and automation.

RQ2: What are the spatial characteristics and consequences of adopting IoT?

During the early phase of this project (2011-2012), Article 1 initiated discussions on the spatial characteristics and consequences of adopting IoT. It pointed out that the IoT deployment was place-rooted in complex local and global agents' frameworks. At that time, the place-rooted aspect mainly referred to the physical locality of the connected "Things" and the complex local and global agents' frameworks meant the development of IoT applications that involved a co-creation by heterogeneous actors from different geographic reaches.

At the end of the project, however, the spatial characteristics of IoT deployment were synthesised as the contextuality of relevance and connectivity. Relevance deals with the motivations underlying the division of labour in an IoT network. It motivates why to connect the local things to the global Internet. Connectivity deals with the coordination part in an IoT network. It coordinates the physical network connectivity and system interoperability connectivity of linking physical things to the digital Internet.

By applying a physical-world centred view, the spatial patterns of IoT can be geographically dispersed (e.g., smart city), or geographically concentrated (e.g., smart factory) for geographically fixed (e.g., smart home) or geographically mobile (e.g., smart logistic) services. Using a digital-world centred view, the digital flows in an IoT system do not travel freely, but rather are affected by how are they connected (e.g., a network infrastructure) and how these flows interact with each other (e.g., interoperability). Interoperability is another type of connectivity influenced by digital governance that includes social, political, and organisational factors. An integrated view of the digital-physical world thus contributes to a relational conceptualisation of the economic space that is affected by IoT deployment, wherein distance is not only a measurement of the physical, institutional, social, and organisational proximity; it is also a measurement of connectivity and interoperability. Thus, two proximities are proposed here for measuring connectivity and interoperability in an IoT system, i.e., information network proximity (e.g., an IoT network infrastructure) and information system proximity (e.g., IoT operational platforms). However, the digital-physical dimension restricts our understanding of IoT as being merely information flows.

Since the purpose of adopting IoT technologies is to provide useful information and valued services to potential users, the value of IoT deployment is more about knowledge flows (e.g., the discussions on RQ1) than information flows. From a knowledge production point of view, knowledge and information are the dual basis of innovation, and innovation creates new information technology (as elaborated on in section 3.3.1). In this study, the digital-physical dimension (i.e. geography of information) is integrated with the local-global dimension (i.e. the geography of knowledge and innovation). When the production of knowledge, especially the tacit type of knowledge, expands from being human-centred to a combination of human and non-human actors, then social economic activities are transformed into a more complex division of labour in time and space.

According to Storper's (2009:13) definition, the structure of context is defined by the division of labour and the actors' networks. Based on this definition, this thesis theorises the contextuality of relevance and connectivity as the spatial characteristics of adopting IoT technologies. Relevance points out why to connect local things to the global Internet. It explains the motivations underlying the division of labour. Connectivity describes how to connect physical things to the digital Internet (e.g., network connectivity) and how to enable interactions between things and things or things and people (e.g., interoperability connectivity). It is a crucial part of coordinating IoT systems.

The mass adoption of IoT technologies may result in the outsourcing and offshoring of routine tasks to IoT systems or the co-handling of advanced tasks by artificial intelligence-assisted human activities. The rise of the IoT age may lead to the scenario described by Storper (2009) as a great transformation of "distributed contexts". So far, society has just begun to adopt IoT technologies, so this is my speculation. However, if we come to this scenario, future competitiveness may rely on how much a firm, a region, or a nation is able to relate its specialisation to the distributed contexts of tasks and how well these entities can generate knowledge and innovation from a "context-based" coordinating and motivating of economic actions.

Theme 2 concludes that contexts affect the production of IoT applications through various aspects of the spatial structure of knowledge and innovation networks. The adoption of IoT services is thus affected by different levels of contexts, ranging from the individual/households level (e.g., simply being cool and bringing convenience), to organisations (e.g., increasing actual productivity and reducing costs), to the societal level (e.g., tackling societal challenges such as sustainable transportation/manufacturing or an aging populations, even food security or improvement in well-being for individuals as well as society).

These aspects are elaborated on in the following three research questions:

RQ3: In what way does place matter for the production of IoT applications?

The production of IoT applications can be understood as knowledge-intensive innovation activities that are spatially affected by multiple contextual factors, such as the *knowledge bases*

(Asheim, 2007; Asheim et al., 2007; Asheim and Gertler, 2005; Asheim and Hansen, 2009); a range of geographical or geographically related proximities (Boschma and Frenken, 2010; Gertler, 2003; Morgan, 2004); and the KIBS-driven knowledge dynamics in multilevel contexts (Bryson and Daniels, 2007; Coombs and Miles, 2000; Den Hertog, 2000; Muller and Doloreux, 2009; Muller and Zenker, 2001; Strambach, 2008). Overall, the development of IoT applications is more spatially constrained than the development of IoT platforms. Nevertheless, the current fragmentation of IoT platforms may indicate the rising importance of information system proximity when developing IoT applications. From this point of view, the spatial configurations of IoT application production are complex. One way to illustrate it is using the "distributed platforms" model of a global production framework (Cooke, 2017). Another way is the multilevel knowledge co-creation point of view. The spatial configuration of innovation networks using a co-creation view is to form a temporal and flexible network of actors that is "project"-based. In this type of innovation network, the KIBS' role is crucial in order to facilitate interactive learning of the multilevel dynamics that transcends the geographical boundary. The multilevel knowledge co-creation point of view is developed further in Article 2.

Article 2 reveals that place matters for the development of the technologies ("region as test-bed") and the value creation of these IoT services. These aspects are coupled with the intermediate role of Knowledge-intensive business services for the co-creation of a Greener future. The development of six Green IoT services demonstrates that knowledge, competence, and trust accumulated in telecom and transportation by the nexus of KIBS growing around Multinational Corporations in the Gothenburg Region laid the foundations for that region to become a test-bed for Green IoT transport/vehicles services. The knowledge lies in the state of constant upgrading and changing from inside the region or outside the region. KIBS are in this respect at the core of activities taking place on a multilevel geographical scale, where local presence and international reach through contacts and clients are essential for the knowledge transfer. Knowledge and policy networks are complex and they take time to develop. This process creates a regional competitive advantage that can be sustained over time and makes it more difficult for actors to leave for other locations.

RQ4: In what way does place matter for the adoption of IoT services?

The reasons to adopt an IoT service can vary for different types of users. Theme 2 analyses three levels of adopters. **Individual/household** adopters seek service characteristics such as convenience, functional usefulness and entertainment. Their adoptions might be affected by contextual factors like age, gender, access, cognitive abilities, peer pressure, and institutional, social and cultural contexts. **Organisation/industry** adopters seek service characteristics such as productivity, cost reduction, developing new business models. Their adoptions might be affected by contextual factors, i.e., organisational/industry context, competitive pressure, and institutional, social and cultural contexts. **Societal (cities, regions, and nations)** adopters seek service characteristics, such as sustainability, optimizing existing public services, or providing new public services that address societal challenges. Their adoptions might be affected by contextual factors like infrastructure and geographical conditions, governance, peer pressure, and institutional, social, and cultural contexts.

Article 3 extends the discussion on contextual factors during public IoT service implementation in cities. It concludes that contextual factors like public motives, user preferences, and governance can impact the evolution of service characteristics during the adoption of global identical IoT technologies. When implementing the smart PBS schemes in Gothenburg and Hangzhou, the technological characteristics were almost identical. The service characteristics, on the other hand, were diverged through time due to contextual factors and service providers' competences.

RQ5: How do public polices facilitate the emergence of the IoT industry?

The role of public policy via various policy initiatives is an important institutional factor to help facilitate the uptake of the IoT, which affects the adoption of the IoT in society. Since the IoT industry is a new technologically based industry, the path-creation approach is applied here to examine the role of public policies in new technological-based industry emergence.

Inspired by a resource-formation view of path creation, the role of the public policy/government is to facilitate the creation and movement of key resources for new industry emergence by actors at internal, national and sub-national levels. These key resources are knowledge, finance, market, and legitimacy. Articles 1 and 4 go a step forward to define the role of such policies in new technological-based industry path creation during the different periods of IoT emergence.

The case of the IoT pilot city, Wuxi, in Article 1 demonstrates that during the early phase of the emerging IoT vision, the Chinese central government and the Wuxi municipal government responded as the initiator and core player, respectively, in creating the IoT industry in their venues. The EU case reveals that *supranational resource concertation* describes the key role for EU institutions to take to facilitate the path creation of the IoT industry. Both cases indicate that public policy is one important driver for the emergence of the IoT industry. Even though public policies alone cannot create an industry, and indeed, in the best case situation, policies can facilitate the emergence of the embryonic industry.

The policy implications are several. First, the government initiative must be followed by the value chain and business models development by the industry (based on Article 1). Second, as the path-creation process is non-linear, policy-makers should act proactively, which is not based on prediction, but rather on the emerging future direction of the industry. Third, the future directions and visions of an emerging industry are an evolving process. Thus, mechanisms need to be built to support policy-making as a dynamic resource concertation process.

Figure 13 summarises the relationship between IoT and context in these two research themes. The concept of context is applied in three ways. In Theme 1, a combined digital-physical and local-global framework is used to underpin context as the local/regional specialisations to the globalisation process. In Theme 2, an integrated local-global and KIBS-driven multilevel knowledge dynamics is applied to understand context as the knowledge/innovation networks for the production of IoT applications. A combined digital-physical dimension within a characteristics-based service innovation framework is used to develop the social-economic contexts for the adoption of IoT service on different geographical levels.

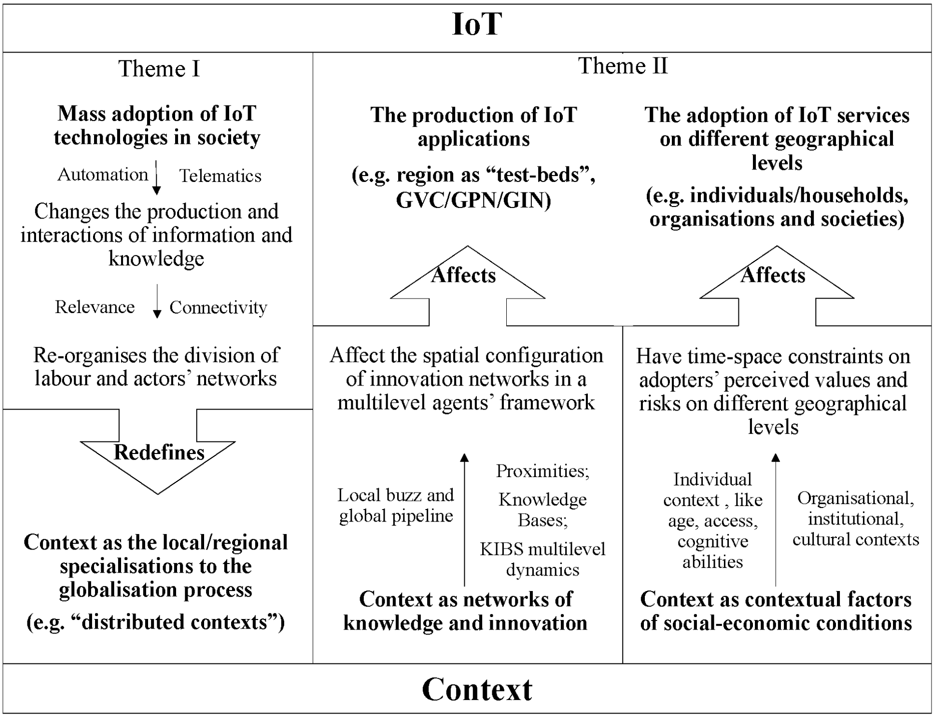

Figure 13: The relationship between IoT and context (Source: Author)

5.2 MAJOR THEORETICAL CONTRIBUTIONS

Overall, this thesis has developed an economic-geographic theory of IoT by exploring the relationship between IoT and context, and it thus contributes to the understanding of spatial characteristics and consequences of IoT deployment. It is, therefore, in a broad sense also pushing forward the theory development of the changing geography of specialisation, now being driven by new ICTs. One innovation in the thesis is to develop the geography of context in an integrated spatial framework that has three dimensions: 1) the digital-physical dimension; 2) the local-global dimension; and 3) the multilevel dimension of knowledge dynamics. In this way, the work integrates the geography of information with the geography of knowledge and innovation. This integrated framework enables a further exploration of the changing geography of specialisation driven by the mass adoption of IoT technologies.

In Theme 1, a key theoretical contribution is proposing the "contextuality" of relevance and connectivity as the spatial characteristics of adopting IoT technologies (see Figure 8 on page 47). This view integrates the digital-physical dimension with the local-global dimension. Such integration is built upon the theorisation of seeing IoT as a producer and container of knowledge, including the tacit knowledge. When non-human actors are complementing humans in the division of labour of knowledge production, such mass adoption of IoT technologies complicates the spatial configurations of production and services. However, such complexity can be explained by both relevance and connectivity. In an IoT network, relevance explains the motivations underlying the division of labour, which motivates why society want to connect local things to the global Internet; while connectivity handles the coordination part, which links the physical things to the digital Internet through network connectivity and interoperability connectivity. The "contextuality" of relevance and connectivity, thus, connects the digital-physical dimension of an IoT system with the local-global dimension of knowledge production and interactions, thereby providing an integrated spatial framework that explains the spatial characteristics of adopting IoT technologies.

The other theoretical contribution in Theme 1 is linking the information and knowledge flows with innovation in the IoT service context (i.e. automation). Based on Kellerman's information sequence (2002:4), this study developed an "information sequence loop" (see Figure 14), the information sequence loop includes the original four sequential logics between data, information, knowledge, and innovation/ information technologies, and added a fifth process, i.e., the optimising process. Information technologies enhance the collection of data, optimise its transformation to useful information, and hence help further generating knowledge and innovation. In other words, information technologies optimise the earlier four processes and turn the information sequence into a loop. This looped view between information, knowledge, and innovation/information technologies was developed by Article 1. It explains how IoT enables innovations via offering smart services through automation and telematics.

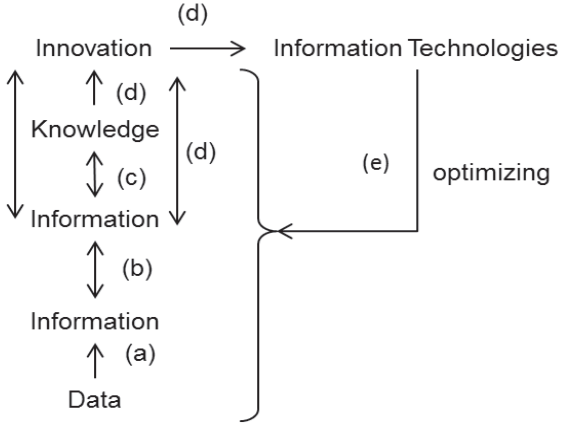

Figure 14: The Information Sequence Loop (Source: Author's extension based on Kellerman's information sequence mode)

Theme 2 proposes a model (see Figure 15) that explicitly includes the contextual dynamics for public service innovations that utilise IoT. The model is built by combining the theories from the characteristics-based approach already in the service innovation literature (Lancaster, 1966; Saviotti and Metcalfe, 1984; Gallouj and Weinstein, 1997) and the geography of information (Kellerman, 2002; Wilson et al., 2013). Service innovation theory shows that factors such as the competencies of the service providers and users, the technical and non-technical characteristics (such as branding and organisation) influence the service characteristics during the innovation processes. The geography of information technologies stresses that even though the technologies are pervasive, the production and consumption of them is place-dependent. Local conditions, such as government policies, specific customs, etc. can all influence the deployment and development of information technologies in a certain place. An integration of the two explains why geography matters when globally identical technologies are adopted at different locations. Since the model is developed from the general theories of information technologies, it is suggested that it can be applied to analyse other types of digital public service platforms than only the IoT services. This model was developed by Article 3. The application of a characteristics-based approach has paved the way to bridge the conceptualisation of IoT applications with the adoption of IoT services, because this approach transforms the non-technical and technical aspects of an IoT system to service characteristics that are user-centric.

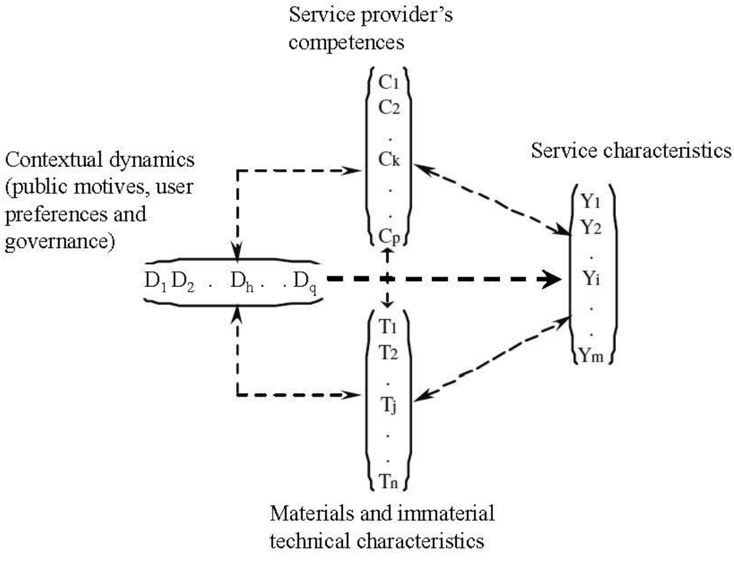

Figure 15: The contextual dynamics of public service innovations utilizing IoT (Source: Author)

In Theme 2, the author contributes to the theory development of path creation by inserting a supranational EU dimension. An analytical framework (Table 9) is developed to discuss the role of EU policies for facilitating the emergence of new technological-based industries. Combined a resource-formation view of path creation (Binz et al., 2016) with EU policy-making process, the author defines path creation in the EU context as to facilitate the creation and movement of key resources by actors at the internal, national and sub-national levels. A resource-based view of early path creation helps to elucidate the role of governments in aligning and anchoring critical resources in multi-level institutional environments. This view transcends the national border, thus shed lights on inserting the supranational EU dimension. The EU institutions can play a role to facilitate new technological-based industrial path creation through the regulative, financial and normative power, although the capabilities vary in different policy areas. The role of EU public policies in path creation is named as "supranational resource concertation". The EU decision-making is a combination of institutional entrepreneurship and time-consuming bargaining process. Because co-decision is the fundamental principle, resources and decision-making power are distributed among different institutions and between political groups at the EU level. For this reason, resource concertation is the way for the EU to set up new policy issues and implement unified policy actions for new industry formation. The four key resources are knowledge, markets, investment, and technology. In the framework, each key resource formation is defined in the EU policy-making context and divided into two policy-making phases, i.e., the agenda-setting phase and the policy management phase. A chord of policy actions is identified to support supranational resource concertation.

Table 9: Key resource formation for path creation during the EU policy-making process (Source: Author's elaboration and adaptation based on Binz et al., 2016 and Princen, 2011)

Key resources formation	**Definition**	**Agenda-Setting phase**	**Policy Management Phase**
Knowledge creation	Policy activities that create new technological knowledge and related competencies, including the activities to support interactions of actors and networks at the international, national and sub-national levels	Framing policy issues; expert groups, forums, and public consultations	Collaborative research and innovation projects; Conferences, and Seminars; Interactions with key stakeholders at different spatial levels
Markets formation	Policy activities that reduce the national and industrial barriers for the creation of new market segments	-	Policy actions that support single market integration; Demonstration or pilot projects; Standardisation and regulation development
Investment mobilisation	Policy activities that invest in collaborative research and innovation projects	-	Implementing collaborative research and innovation projects
Technology legitimacy	Policy activities that facilitate the acceptance and compliance of new technologies in the EU policy venue and institutional structures	Locating a policy venue; policy community building; claiming authority	Institutional entrepreneurship, including the creation of new regulations and the amendment of existing regulations; the creation and growth of interest groups and their lobbying activities

This framework is developed in Article 4 and was used to analyse the role of EU IoT public polices for facilitating the path creation of IoT industry. It can be applied to discuss the emergence of other new technological-based industries.

5.3 Outlook on future research

As we are now approaching the mass adoption of IoT technologies in society, many exciting opportunities for future research will likely open in the near future.

First, it will be timely to study the multilevel knowledge dynamics between the interface of sustainable manufacturing, IoT and extra-regional linkages. Since IoT technologies enable innovations via automation and telematics, it is believed that companies in the industrial sector are to exploit the potential of IoT in renewing and re-organising production and products to lead the digital transformation for sustainable growth. The recent debate in extra-regional linkages are focusing on trade, technological and organizational perspectives such as technological related variety of the firms, FDI and trade linkages, and in headquarter-subsidiaries interactions. Little attention has been paid to the advanced service activities that bring in extra-regional linkages by local presence and international reach through contacts and clients. These extra-regional linkages provide knowledge, technology and dissimilar competences to the nexus of business and policy networks in the region for sustainable manufacturing. The externally connected engineering technology and organizational consultants and other forms of advanced service providers can import fresh knowledge, cutting-edge technology and state-of-the-art way of doing things to the manufacturing firms in the region. Therefore, it is interesting to analyse the dynamics of the regional embeddedness of sustainable manufacturing into governance, cross-sector and policy initiatives and institutions.

The second interesting topic is one that can empirically examine the spatial consequences of IoT adoption. In this project, the author's exploration of this topic remained in theory because the current adoption of IoT has not been comprehensive enough in society to show the spatial consequences in actual production. In theory, that might lead to a "context-based" coordinating and motivating of economic actions in tasks. Based on Storper's (2009) "distributed contexts" theory, such "context-based" geography of specialisation can be further studied in at least four respects. The first concerns the current intra-organisational borders. Could these borders be blurred further, which would contribute to a flatter distribution of organisational hierarchies? For instance, there might be a transformation from big vertically integrated producers to networked heterogeneous production units. The second question relates to the physical geographical proximity. Due to automation and telematics, could physical geographical distance play a lesser role for intra- and inter-organisational relations? The third question raises the possibilities of a dissolving boundary appearing between the formal and the informal processes of coordinating production relationships. Could IoT technologies facilitate a more flexible formalisation of such production networks? The fourth question turns to the local-global debate of innovation activities. Will these IoT technologies eventually enhance the overall global pipeline effect of knowledge creation and sourcing?

The third interesting research area for future research would be looking into the IoT business models. This thesis provides an in-depth analysis of the spatial characteristics of IoT for both the production and the adoption of IoT technologies. Since these spatially embedded mechanisms unlock the potentials of IoT during its value creation process, the study paves the way to explore the creation of business models for IoT services still further. So far, the research on IoT business model development has been focusing on the technological potentials of IoT, e.g., sensors for service and digitally charged products (Fleisch et al., 2014). This supply perspective addresses such questions as "what can be connected?" and "what kind of new services can be realised?" However, the demand perspective is still being downplayed. The demand perspective is user-centric and asks questions like "What kind of values can be created by connecting these things for whom?" and "Are these values interesting enough for the users to want to adopt?" Many failed IoT products have neglected the demand side of IoT adoption. This thesis provides a re-conceptualisation of those combining technology attributes, their contextual factors and the network of supply actors to the user-centric service characteristics (Figure 15). This model can be further evaluated to add the demand side to IoT business model creation.

Fourth, it is important to ask whether the current regulatory framework is adequate for the perceived IoT future. The role of government as a regulator of the emerging IoT issues has not been discussed yet in detail. That is due to the fact that currently IoT is not regulated. It does make sense, however, that when the technologies reach mass adoption, the necessity for regulation will be clearer. For instance, during the early 2010s, the EU had debates on having a regulative framework for IoT, but it did not reach a consensus. When real problems occur during the process of mass adoption, issues like trust, privacy, security, and consumer protection may come back to the legislative table. How will different countries and regions deal with the legislative aspect of the IoT? Would there be a global IoT governance structure as today's Internet, or a divergence and fragmentation adopted for handling these regulatory issues? These questions lead to the regulative competition of national/supranational level and government/corporate level. The latter regulative aspect comes to the public debate on whether the big techs are so powerful and profitable that they should be regulated. Underlying this debate is the divergence of views on who is the true innovator for IoT? The upstream patent-holding big techs and the downstream application developers may well consider themselves to be more important than the other. These are crucial questions to raise and address if the industry and society want to benefit fully from adopting the IoT technologies.

Without a vision, people can't create a future for it, but only react to it. A bold idea would be to integrate Theme 1 and Theme 2. The context in Theme 2 that affects the production of IoT applications and the adoption of IoT services is based on current situations. Yet the context that is redefined by mass IoT adoption is pointing toward future scenarios. If we apply a long-term perspective, these two contexts will likely eventually merge. By then, how will the "distributed contexts" of local/regional specialisations to the globalisation process affect the production of IoT applications? In other words, what could be the geographical configuration of innovation networks when non-human actors are increasingly becoming the producers and carriers of tacit knowledge?

People often over-estimate how much technology can change our life within a short term, while they under-estimate how far technologies can advance over a longer period. In the 1980s, it would be hard to imagine how much the Internet and mobile technologies have already changed our everyday lives in 2017. Based on the development pace of machine learning and artificial intelligence, it is very likely that an increasing number of knowledge productions will be outsourced to or co-handled by autonomous intelligent systems. What then will remain the advantages of human intelligence? Machine intelligence and human intelligence are good at different types of knowledge creation. For example, humans may not be so good at dealing with repetition and large scopes of data processing, but we can imagine and create. Computers in the foreseeable future cannot compete with these more arts-based tasks. Would the complementary features between these two intelligences some day create a new division of labour in knowledge production? If so, will the arts-based symbolic knowledge that is most place sensitive in the value chain, gain increasing importance for affecting the spatial configurations of knowledge networks? An economic-geographic approach can provide some insightful perspectives indeed for that kind of more human-centred IoT research.

REFERENCES

Aguzzi S., Bradshaw D., Canning M., Cansfield M., Carter P., Cattaneo G., Gusmeroli S., Micheletti G., Rotondi D. and Stevens R. (2014) *Definition of a Research and Innovation Policy Leveraging Cloud Computing and IoT Combination*. A study prepared for the European Commission DG Communications Networks, Content & Technology. Luxembourg: Publications Office.

Alvstam C.G., Ström P. and Wentrup R. (2016) Heterogeneous economic space in a global archipelago: an economic-geography perspective of emerging markets. In: Merchant H. (ed.), *Handbook of Research on Emerging Markets*, Cheltenham, UK: Edward Elgar, 38–61.

Asheim B. (2007) Differentiated Knowledge Bases and Varieties of Regional Innovation Systems. *Innovation: The European Journal of Social Science Research* 20(3): 223–241.

Asheim B., Boschma R. and Cooke P. (2011) Constructing Regional Advantage: Platform Policies Based on Related Variety and Differentiated Knowledge Bases. *Regional Studies* 45(7): 893–904.

Asheim B. and Coenen L. (2005) Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy* 34(8): 1173–1190.

Asheim B., Coenen L., Moodysson J. and Vang J. (2007) Constructing knowledge-based regional advantage: implications for regional innovation policy. *International Journal of Entrepreneurship and Innonvation Management* 7(2–5): 140–155.

Asheim B., Coenen L. and Vang J. (2007) Face-to-Face, Buzz, and Knowledge Bases: Sociospatial Implications for Learning, Innovation, and Innovation Policy. *Environment and Planning C: Government and Policy* 25(5): 655–670.

Asheim B. and Gertler M.S. (2005) The Geography of Innovation: Regional Innovation Systems. In: Fagerberg J. and Mowery D.C. (eds), *The Oxford Handbook of Innovation*, Oxford: Oxford University Press, 291–317.

Asheim B. and Hansen H.K. (2009) Knowledge bases, talents, and contexts: On the usefulness of the creative class approach in Sweden. *Economic Geography* 85(4): 425–442.

Ashton K. (2009) That "Internet of Things" Thing: In the real world, things matter more than ideas. *RFID Journal:* 1–2.

Atzori L., Iera A. and Morabito G. (2010) The Internet of Things: A survey. *Computer Networks*: 2787–2805.

Atzori L., Iera A. and Morabito G. (2017) Understanding the Internet of Things: definition, potentials, and societal role of a fast evolving paradigm. *Ad Hoc Networks* 56: 122–140.

Balland P.A., Belso-Martínez J.A. and Morrison A. (2016) The Dynamics of Technical and Business Knowledge Networks in Industrial Clusters: Embeddedness, Status, or Proximity? *Economic Geography* 92(1): 35–60.

Banchoff T. (2002) Institutions, Inertia and European Union Research Policy. *Journal of Common Market Studies* 40(1): 1–21.

Barlow C.A. (2012) Interviews. Mills A., Durepos G. and Wiebe E. (eds), *Encyclopedia of Case Study*

Research, Thousand Oaks, CA: SAGE Publications, 496–499.

Bassi A. and Lange S. (2013) The Need for a Common Ground for the IoT: The History and Reasoning Behind the IoT-A Project. In: Bassi A., Bauer M., Fiedler M., Kramp T., van Kranenburg, R., Lange, S. and Meissner, S. (eds), *Enabling Things to Talk*, Berlin, Heidelberg: Springer, 13–16.

Bathelt H., Malmberg A. and Maskell P. (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography* 28(1): 31–56.

Bhaskar R. (1975) *A realist theory of science*. Leeds: Leeds Books.

Bhaskar R. (1979) *The Possibility of Naturalism: A Philosophical Critique of the Contemporary Human Sciences*. Brighton: Harvester.

Bhaskar R. (1989) *Reclaiming reality: A critical introduction to contemporary philosophy*. London: Verso.

Bhaskar R. (2009) *Scientific Realism and Human Emanicipation*. London and New York: Routledge.

Bhaskar R. and Hartwig M. (2010) *The Formation of Critical Realism: A Personal Perspective*. London and New York: Routledge.

Binz C., Truffer B. and Coenen L. (2016) Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing. *Economic Geography* 92(2): 172–200.

Boggs J.S. and Rantisi N.M. (2003) The 'relational turn' in economic geography. *Journal of Economic Geography* 3(2): 109–116.

Boschma R. (2005) Proximity and Innovation: A Critical Assessment. *Regional Studies* 39(1): 61–74.

Boschma R. (2014) Constructing Regional Advantage and Smart Specialisation: Comparison of Two European Policy Concepts. *Scienze Regionali* 13: 51–68.

Boschma R. and Frenken K. (2010) The spatial evolution of innovation networks. A proximity perspective. In: Boschma R. and Martin R. (eds), *The Handbook of Evolutionary Economic Geography*, Cheltenham and Northampton, MA: Edward Elgar, 120–135.

Boschma R. and Frenken K. (2011) The emerging empirics of evolutionary economic geography. *Journal of Economic Geography* 11(2): 295–307.

Boschma R., Frenken K., Bathelt H., Feldman M., and Kogler D. (2012) Technological relatedness and regional branching. In: Bathelt H., Feldman M. and Kogler D. (eds), Beyond territory. *Dynamic geographies of knowledge creation, diffusion and innovation*. London: Routledge, 64-81.

Bryman A. and Bell E. (2015) *Business research methods*. 4th Edition. Oxford: Oxford University Press.

Bryson J.R. and Daniels P.W. (eds) (2007) *The Handbook of Service Industries*. Cheltenham and Northampton, MA: Edward Elgar.

Cairncross F. (2001) *The death of distance : how the communications revolution is changing our lives*. Boston, MA: Harvard Business School Press.

Canhoto A.I. and Arp S. (2016) Exploring the factors that support adoption and sustained use of health and fitness wearables. *Journal of Marketing Management* 33(1-2): 32–60.

Carayannis E.G. and Wang V. (2008) The Role of the Firm in Innovation Networks and Knowledge Clusters. In: Carayannis E.G., Assimakopoulos D.G. and Kondō M. (eds), *Innovation Networks and Knowledge Clusters: Findings and Insights from the US, EU and Japan*, Basingstoke, UK: Palgrave Macmillan, 1–20.

Carlsson B. and Stankiewicz R. (1991) On the nature, function and composition of technological systems. *Journal of Evolutionary Economics* 1(2): 93–118.

Castells M. (1996) *The Rise of the Network Society, The Information Age: Economy, Society and Culture*. Volume I. Oxford: Blackwell.

Castells M. (2004) *The Power of Identity. The Information Age: Economy, Society and Culture*. Volume II. Oxford: Blackwell.

Castells M. (2010) *End of Millennium. The Information Age: Economy, Society and Culture*. Volume III. Oxford: Blackwell.

Chen S.H. (2004) Taiwanese IT firms' offshore R&D in China and the connection with the global innovation network. *Research Policy* 33(2): 337–349.

Chesbrough H. and Spohrer J. (2006) A research manifesto for services science. *Communications of the ACM* 49(7): 35.

Clark G.L. (1998) Stylized Facts and Close Dialogue: Methodology in Economic Geography. *Annals of the Association of American Geographers* 88(1): 73–87.

Coe N.M., Hess M., Yeung H.W.-C., Dicken P. and Henderson J. (2004) 'Globalizing' regional development: a global production networks perspective. *Transactions of the Institute of British Geographers* 29(4): 468–484.

Coenen L., Asheim B., Bugge M.M. and Herstad S.J. (2016) Advancing regional innovation systems: What does evolutionary economic geography bring to the policy table? *Environment and Planning C: Government and Policy* 35 (4): 600-620.

Coffey W.J .(2000) The geographies of producer services. *Urban Geography* 21(2): 170–183.

Cohen W.M. and Levinthal D.A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly* 35(1): 128.

Collier A. (1994) *Critical Realism: An Introduction to Roy Bhaskar's Philosophy*. London: Verso.

Consoli D. and Elche-Hortelano D. (2010) Variety in the knowledge base of Knowledge Intensive Business Services. *Research Policy* 39(10): 1303–1310.

Cooke P. (2005) Regionally asymmetric knowledge capabilities and open innovation: Exploring 'Globalisation 2' - A new model of industry organisation. *Research Policy* 34(8): 1128–1149.

Cooke P. (2007) To Construct Regional Advantage from Innovation Systems First Build Policy Platforms. *European Planning Studies* 15(2): 179–194.

Cooke P. (2008) Asymmetric Knowledge, Digital Knowledge Flow Platforms and Regional Innovation Systems. In: Carayannis EG, Assimakopoulos DG, and Kondō M (eds), *Innovation networks and knowledge clusters : findings and insights from the US, EU and Japan*, Basingstoke, UK: Palgrave Macmillan, 89–109.

Cooke P. (2017) Complex spaces: global innovation networks territorial innovation systems in information communication technologies. *Journal of Open Innovation: Technology, Market, and Complexity* 3(9): 1–23.

Coombs R. and Miles I. (2000) Innovation, Measurement and Services: The New Problematique. In: Metcalfe JS and Miles I (eds), *Innovation Systems in the Service Economy: Measurement and Case Study Analysis*, Boston, MA: Springer, 85–103.

Council of the European Union (2008) *Council Conclusions on future networks and the Internet.* Brussels.

Cox J.W. and Hassard J. (2010) Triangulation. Mills A., Durepos G. and Wiebe E. (eds), *Encyclopedia of Case Study Research*, Thousand Oaks, CA: SAGE Publications, 945–949.

Crooks E. (2017) The Internet of Things: industry's digital revolution. *Financial Times*, 27 June.

Crotty M.J. (1998) *The Foundations of Social Research: Meaning and Perspective in the Research Process*. London, Thousand Oaks, New Delhi: SAGE Publications.

de Vries E.J. (2006) Innovation in services in networks of organizations and in the distribution of services. *Research Policy* 35(7): 1037–1051.

Demirdirek H. (2012) Subjectivism. Mills A, Durepos G, and Wiebe E (eds), *Encyclopedia of Case Study Research*, Thousand Oaks, CA: SAGE Publications, 904–906.

den Hertog P. (2000) Knowledge Intensive Business Services As Co-Producers of Innovation. *International Journal of Innovation Management* 4(4): 4–6.

Denzin N.K. (2012) Triangulation 2.0. *Journal of Mixed Methods Research* 6(2): 80–88.

Denzin N.K. (2017) *Sociological Methods: A Sourcebook*. Abingdon, Oxon: Routledge.

Dicken P. (2015) *Global Shift: Mapping the Changing Contours of the World Economy*. 7th Edition. London: SAGE Publications.

Djellal F. and Gallouj F. (2005) Mapping innovation dynamics in hospitals. *Research Policy* 34(6): 817–835.

Dodge M. and Kitchin R. (2001) *Atlas of Cyberspace*. London: Addison-Wesley.

Dolles H., Alvstam C.G. and Ström P. (2013) The changing competitive landscape in Euro-Asia business. *Asian Business & Management* 12(5): 499–502.

Dosi G. (1982) Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy* 11(3): 147–162.

Dusyk N. (2011) Downstream Effects of a Hybrid Forum: The Case of the Site C Hydroelectric Dam in British Columbia, Canada. *Annals of the Association of American Geographers* 101(4): 873–881.

Dutton W.H. (2014) Putting things to work: social and policy challenges for the Internet of Things. *info* 16(3): 1–21.

Eisenhardt K.M. (1989) Building Theories from Case Research. *The Academy of Management Review* 14(4): 532–550.

Ernst D. and Kim L. (2002) Global production networks, knowledge diffusion, and local capability formation. *Research Policy* 31(8–9): 1417–1429.

European Commission (2014) *Final report: High-Level Group on Business Services.* Brussels.

European Commission (2016) *Advancing the Internet of Things in Europe*. Brussels: 5–38.

Faulconbridge J.R. (2006) Stretching tacit knowledge beyond a local fix? Global spaces of learning in advertising professional service firms. *Journal of Economic Geography* 6(4): 517–540.

Feldman M.P. (1994) *The Geography of Innovation*. Economics of Science, Technology and Innovation, Dordrecht, Netherlands: Springer.

Fleisch E. (2010) *What is the Internet of Things? An Economic Perspective. Auto-ID Labs White Paper WP-BIZAPP-053*. Available from: www.autoidlabs.org (accessed 30 July 2017).

Fleisch E., Weinberger M. and Wortmann F. (2014) Business Models for the Internet of Things. *Bosch IoT Lab:* 1–18.

Fletcher A.J. (2017) Applying critical realism in qualitative research: methodology meets method. *International Journal of Social Research Methodology* 20(2): 181–194.

Forman C., Goldfarb A. and Greenstein S. (2005) How did location affect adoption of the commercial Internet? Global village vs. urban leadership. *Journal of Urban Economics* 58(3): 389–420.

Foroohar R. (2017a) Echoes of Wall Street in Silicon Valley's grip on money and power. *Financial Times*, 3 July.

Foroohar R. (2017b) Release Big Tech ' s grip on power. *Financial Times*,18 June.

Frenken K. and Boschma R. (2007) A theoretical framework for evolutionary economic geography: Industrial dynamics and urban growth as a branching process. *Journal of Economic Geography* 7(5): 635–649.

FTC (2015) Internet of Things Privacy & Security in a Connected World. Report of Federal Trade Commission, Washington. D.C.,US, January. Available from: https://www.ftc.gov/system/files/documents/reports/federal-trade-commission-staffreport-november-2013-workshop-entitled-internet-things-privacy/150127iotrpt.pdf (accessed 15 May 2017).

Gallouj F. and Weinstein O. (1997) Innovation in services. *Research Policy* 26(4): 537–556.

Gallouj F. and Zanfei A. (2013) Innovation in public services: Filling a gap in the literature. *Structural Change and Economic Dynamics* 27:89-97.

Garud R. and Karnøe P. (2001) Path Dependence as a Process of Mindful Deviation. In: Garud R. and Karnøe P. (eds), *Path dependence and creation*, Hove, East Sussex: Psychology Press, 1–40.

Gelernter D. (1993) *Mirror Worlds*. Oxford: Oxford University Press.

Gertler M.S. (2003) Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there). *Journal of Economic Geography* 3(1): 75–99.

Glaser B.G. (1992) *Emergence vs forcing: Basics of grounded theory analysis*. Mill Valley, CA: Sociology

Press.

Gottschalk P. (2009) Maturity levels for interoperability in digital government. *Government Information Quarterly* 26(1): 75–81.

Granovetter M. (1985) Economic Action and Social Structure: The Problem of Embeddedness. *American Journal of Sociology* 3(3): 69–83.

Grossman G.M. and Rossi-Hansberg E. (2008) Trading tasks: A simple theory of offshoring. *American Economic Review* 98(5): 1978–1997.

Harvey D. (1989) *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change.* Oxford: Wiley-Blackwell.

Helpman E. (1998) General Purpose Technologies and Economic Growth: Introduction. In: Helpman E. (ed.), *General Purpose Technologies and Economic Growth*, Cambridge, MA: The MIT Press, 1–13.

Hepworth M. (1986) The geography of technological change in the information economy. *Regional Studies* 20(5): 407–424.

Hillis K. (1999) *Digital sensations : space, identity, and embodiment in virtual reality.* Minneapolis, MN: University of Minnesota Press.

Hsu C.-L. and Lin J.C.-C. (2016) Exploring Factors Affecting the Adoption of Internet of Things Services. *Journal of Computer Information Systems* 1–9.

Hsu C.-W. and Yeh C.-C. (2016) Understanding the factors affecting the adoption of the Internet of Things. *Technology Analysis & Strategic Management* 1–14.

Hunt I. and Draper W.W. (1964) *Lightning in his hand: the life story of Nikola Tesla.* London: SAGE Books.

Inkinen T. (2003) Information society, citizens and everyday life: Does the Internet make a difference in spatial practices? *Fennia*, Geographical Society of Finland 181(1): 25–33.

Inkinen T. (2012) Best practices of the Finnish Government Information Society Policy Programme. *Transforming Government: People, Process and Policy* 6(2): 167–187.

International Telecommunication Union (2005) *The Internet of Things. ITU Internet Report 2005*, Geneva: International Telecommunication Union (ITU).

International Telecommunication Union (2012) Overview of the Internet of things. *Series Y: Global information infrastructure, internet protocol aspects and next-generation networks - Frameworks and functional architecture models*: 22.

IoT Analytics (2015) IoT company database.

IT Strategic Headquarters of Japan (2009) *i-Japan Strategy 2015:Striving to Create a Citizen-Driven, Reassuring & Vibrant Digital Society.* Available from: http://japan.kantei.go.jp/policy/it/i-JapanStrategy2015_full.pdf (accessed 5 August 2017).

Ivarsson I. and Alvstam C.G. (2005) The Effect of Spatial Proximity on Technology Transfer from TNCs to Local Suppliers in Developing Countries: The Case of AB Volvo in Asia and Latin America. *Economic Geography* 81(1): 83–111.

Ivarsson I. and Alvstam C.G. (2011) Upgrading in global value-chains: A case study of technology-learning among IKEA-suppliers in China and Southeast Asia. *Journal of Economic Geography* 11(4): 731–752.

Jacobs W., Koster H.R.A. and van Oort F. (2014) Co-agglomeration of knowledge-intensive business services and multinational enterprises. *Journal of Economic Geography* 14(2): 443–475.

Jansson J. (2008) Inside the Internet Industry: The Importance of Proximity in Accessing Knowledge in the Agglomeration of Internet Firms in Stockholm. *European Planning Studies* 16(2): 211–228.

Jin H. and Liang J. (2015) How should the Chinese government provide information services for Mongol ethnic minority? *Government Information Quarterly* 32(1): 82–94.

Johnson M. (2017) How I learnt to stop worrying and love Big Tech. *Financial Times*,19 June.

Karnøe P. and Garud R. (2012) Path Creation: Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster. *European Planning Studies* 20(5): 733–752.

Ke S., He M. and Yuan C. (2014) Synergy and Co-agglomeration of Producer Services and Manufacturing: A Panel Data Analysis of Chinese Cities. *Regional Studies* 48(11): 1829–1841.

Kellerman A. (1989) *Time, Space, and Society: Geographical Societal Perspectives*. GeoJournal Library, Netherlands: Springer.

Kellerman A. (2002) *The Internet on earth : a geography of information*. West Sussex, England: Wiley.

Kellerman A. (2014) *The Internet as Second Action Space*. New York: Routledge.

Kellerman A. (2016) *Geographic Interpretations of the Internet*. Dordrecht, Netherlands: Springer.

Kim Y., Park Y. and Choi J. (2017) A study on the adoption of IoT smart home service: using Value-based Adoption Model. *Total Quality Management & Business Excellence* 28(9-10): 1149–1165.

Kitchin R. (1998) *Cyberspace: the world in the wires*. New York: Wiley.

Koch A. and Stahlecker T. (2006) Regional innovation systems and the foundation of knowledge intensive business services. A comparative study in Bremen, Munich, and Stuttgart, Germany. *European Planning Studies* 14(2): 123–146.

Kramp T., van Kranenburg R. and Lange S. (2013) Introduction to the Internet of Things. In: Bassi A., Bauer M., Fiedler M., Kramp T., van Kranenburg, R., Lange S. and Meissner S. (eds), *Enabling Things to Talk*, Berlin, Heidelberg: Springer, 1–10.

Kumar N., Hoard B. and Jones C. (2016) *IoT Driven M&A*. Available from: http://www.fticonsulting.com/~/media/Files/us-files/insights/articles/internet-of-things-m-and-a.pdf (accessed 1 August 2017).

Kwan M.P. (2001) Cyberspatial cognition and individual access to information: The behavioral foundation of cybergeography. *Environment and Planning B: Urban Analytics and City Science* 28(1): 21–37.

Lancaster K.J. (1966) A new approach to consumer theory. *Journal of Political Economy* 74(2): 132.

Latour B. (1993) *We have never been modern*. Cambridge, MA: Harvard University Press.

Leamer E.E. and Storper M. (2001) The economic geography of the internet age. *Journal of International Business Studies* 32(4): 641–665.

Lee J., Kao H.A. and Yang S. (2014) Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. *Procedia CIRP* 16: 3–8.

Liu J., Chaminade C. and Asheim B. (2013) The Geography and Structure of Global Innovation Networks: A Knowledge Base Perspective. *European Planning Studies* 21(9): 1456–1473.

Lorentzon S. (1995) The Use of ICT in TNCs: A Swedish Perspective on the Location of Corporate Functions. *Regional Studies* 29(7): 673–685.

Lundvall B.A. (1992) *National systems of innovation : towards a theory of innovation and interactive learning.* London: Pinter.

Lusch R.F. and Vargo S.L. (2006) *The Service-dominant Logic of Marketing: Dialog, Debate, and Directions*. London: Routledge.

MacKinnon D. and Cumbers A. (2007) *Introduction to economic geography : globalization, uneven development and place*. Harlow, UK: Prentice Hall.

Malecki E. (2002) The Economic Geography of the Internet's Infrastructure. *Economic Geography* 8(4): 399–424.

Malecki E. (2010) Global Knowledge and Creativity: New Challenges for Firms and Regions. *Regional Studies* 44(8): 1033–1052.

Malecki E. and Moriset B. (2008) *The Digital Economy: Business Organization, Production Processes, and Regional Developments.* London: Routledge.

Malerba F. and Orsenigo L. (2000) Knowledge, Innovation Activities and Industrial Evolution. *Industrial & Corporate Change* 9(2): 289–313.

Mani Z. and Chouk I. (2017) Drivers of consumers' resistance to smart products. *Journal of Marketing Management* 33(1–2): 76–97.

Manyika J., Chui M., Bisson P., Woetzel J., Dobbs R., Bughin J. and Aharon D. (2015) The Internet of Things: Mapping the value beyond the hype. *McKinsey Global Institute* (June): 144.

Martin H. and Martin Roman (2016) Policy capacities for new regional industrial path development - The case of new media and biogas in southern Sweden. *Environment and Planning C: Government and Policy* 35(3): 518-536.

Martin P.Y. and Turner B.A. (1986) Grounded theory and organizational research. *The Journal of Applied Behavioral Science* 22(2): 141–157.

Martin Roman (2013) Differentiated Knowledge Bases and the Nature of Innovation Networks. *European Planning Studies* 21: 37–41.

Martin Ron (2002) Institutional Approaches in Economic Geography. In: *A Companion to Economic Geography*, Oxford: Blackwell, 77–94.

Martin Ron (2010) Roepke Lecture in Economic Geography—Rethinking Regional Path Dependence: Beyond Lock-in to Evolution. *Economic Geography* 86(1): 1–27.

Maskell P. and Malmberg A. (1999) Localised learning and industrial competitiveness. *Cambridge Journal of Economics* 23(2): 167–185.

Maskell P. and Malmberg A. (2007) Myopia, knowledge development and cluster evolution. *Journal of Economic Geography* 7(5): 603–618.

MIIT (Ministry of Industry and Information Technology of the People's Republic of China) (2011) the Development Program of Internet of Things in the Twelfth Five Year Plan Period. Beijing: MIIT.

Miles I, Kastrinos N, Flanagan K, Bilderbeek R. den Hertog P. Huntink W. and Bouman M. (1995) *Knowledge-intensive business services Users, Carriers and Sources of Innovation. Report to DG13 SPRINT-EIMS.* Available from: https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:75252&datastreamId=FULL-TEXT.PDF (accessed 15 July 2017).

Mills A., Durepos G. and Wiebe E. (2010) *Encyclopedia of Case Study Research.* Thousand Oaks, CA: SAGE Publications.

Mingorance F. (2017) Tech licensing systems that keeps the giants in check. *Financial Times*,1 August.

Morgan K. (2004) The exaggerated death of geography: learning, proximity and territorial innovation systems. *Journal of Economic Geography* 4(1): 3–21.

Moulaert F. and Gallouj C. (1993) The Locational Geography of Advanced Producer Service Firms: the Limits of Economies of Agglomeration. *The Service Industries Journal* 13(2): 91–106.

Mudambi R. and Swift T. (2011) Leveraging knowledge and competencies across space: The next frontier in international business. *Journal of International Management* 17(3): 186–189.

Muller E. and Doloreux D. (2009) What we should know about knowledge-intensive business services. *Technology in Society* 31(1): 64–72.

Muller E. and Zenker A. (2001) Business services as actors of knowledge transformation: The role of KIBS in regional and national innovation systems. *Research Policy* 30(9): 1501–1516.

Neffke F., Henning M. and Boschma R. (2011) How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography* 87(3): 237–265.

Nonaka I., Toyama R. and Konno N. (2000) SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation. *Long Range Planning* 33(1): 5–34.

O'Brien R. (1992) *Global financial integration: the end of geography.* London: Pinter.

OECD (2015) Emerging issues: The Internet of Things. In: *OECD Digital Economy Outlook*, Paris: OECD Publishing, 239–280.

Ohmae K. (1990) *The borderless world: power and strategy in the interlinked economy.* London: Fontana.

Palinkas L.A., Horwitz S.M., Green C.A., Wisdom J.P., Duan, N.H. and Hoagwood, K. (2015) Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Administration and Policy in Mental Health and Mental Health Services Research* 42(5): 533–544.

Patton M.Q. (2014) *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*. Thousand Oaks, CA: SAGE Publications.

Pauly B.M. (2012) Direct Observation as Evidence. Mills A, Durepos G, and Wiebe E (eds), *Encyclopedia of Case Study Research*, Thousand Oaks, CA: SAGE Publications, 302–304.

Pavitt K. (1998) Technologies, products and organization in the innovating firm. *Industrial and Corporate Change* 7(3): 433–452.

Polanyi M. (1966) *The Tacit Dimension*. New York: Anchor Books.

Pratt A.C. (1995) Putting critical realism to work: the practical implications for geographical research. *Progress in Human Geography* 19(1): 61–74.

Ragin C. (1987) *The comparative method: Moving beyond qualitative and quantitative methods*. Berkeley: University of California.

Rakity A., Rehak A. and Jennings T. (2017) *IoT opportunities in 2017 and beyond*. Available from: https://ovum.informa.com/resources/product-content/ovum-iot-viewpoints-opportunities-in-2017-and-beyond.

Rallet A. and Torre A. (1999) Is geographical proximity necessary in the innovation networks in the era of global economy? *GeoJournal* 49(4): 373–380.

Rami K.A. and Inkinen T. (2008) Information technology, communication and networking in software companies of northern Finland. *International Journal of Knowledge Management Studies* 2(3): 320–334.

Raptis H. (2012) Documentation as Evidence. Mills A, Durepos G, and Wiebe E (eds), *Encyclopedia of Case Study Research*, Thousand Oaks, CA: SAGE Publications, 321–322.

Reed M. (2017) Downstream players in the internet of things seek to double dip. *Financial Times*, 28 July.

Riggins F.J. and Wamba S.F. (2015) Research directions on the adoption, usage, and impact of the internet of things through the use of big data analytics. In: *Proceedings of the Annual Hawaii International Conference on System Sciences*, 1531–1540.

Rose K., Eldridge S. and Lyman C. (2015) The internet of things: an overview. *Internet Society* (October): 53.

SAS (2016) *Internet of Things Visualise the Impact*. Available from: http://www.sas.com/content/dam/SAS/bp_de/doc/ebook/iot-visualise-the-impact-2458546.pdf (accessed 23 February 2017).

Saviotti P.P. (1985) An approach to the measurement of technology based on the hedonic price method and related methods. *Technological Forecasting and Social Change* 27(2): 309–334.

Saviotti P.P. (1996) *Technological Evolution, Variety and the Economy*. Cheltenham, UK and Brookfield, USA: Edward Elgar.

Saviotti P.P. and Metcalfe J.S. (1984) A theoretical approach to the construction of technological output indicators. *Research Policy* 13(3): 141–151.

Sayer A. (1981) Abstraction: a realist interpretation. *Radical Philosophy* 28: 6–15.

Sayer A. (2010) *Method in Social Science: Revised 2nd Edition*. London: Routledge.

Sayer A. (2012) *Realism and Social Science*. London: SAGE Publications.

Schoenberger C. and Upbin B. (2002) The Internet of Things (IoT). *Forbes Magazine,* 169(6): 155-160.

Schwanen T. and Kwan M.P. (2008) The Internet, mobile phone and space-time constraints. *Geoforum* 39(3): 1362–1377.

Spohrer J. and Maglio P.P. (2008) The Emergence of Service Science: Toward Systematic Service Innovations to Accelerate Co-Creation of Value. *Production and Operations Management* 17(3): 238–246.

Steen M. (2016) Reconsidering path creation in economic geography: aspects of agency, temporality and methods. *European Planning Studies* 24(9): 1605–1622.

Sterling B. (2005) *Shaping Things*. Cambridge, MA: The MIT Press.

Storper M. (2009) Roepke Lecture in Economic Geography - Regional Context and Global Trade. *Economic Geography* 85(1): 1–21.

Strambach S. (2008) Knowledge-Intensive Business Services (KIBS) as drivers of multilevel knowledge dynamics. *International journal of services technology and management* 10(2–4): 152–174.

Strambach S. (2010) Path dependence and path plasticity: the co-evolution of institutions and innovation–the German customized business software industry. In: Boschma R. and Martin R. (eds), *The Handbook of Evolutionary Economic Geography*, Cheltenham and Northampton, MA: Edward Elgar, 406–431.

Strauss A. and Corbin J. (1990) *Basics of qualitative research : grounded theory procedures and techniques*. Thousand Oaks, CA: SAGE Publications.

Strauss A. and Corbin J. (1994) Grounded theory methodology. In: Denzin N.K. and Lincoln Y.S. (eds), *Handbook of qualitative research*, Thousand Oaks, CA: SAGE Publications, 273–285.

Ström P. and Wahlqvist E. (2010) Regional and firm competitiveness in the service-based economy: Combining economic geography and international business theory. *Tijdschrift voor Economische en Sociale Geografie* 101(3): 287–304.

Suurs R., Hekkert M., Kieboom S. and Smits R. (2010) Understanding the formative stage of technological innovation system development: The case of natural gas as an automotive fuel. *Energy Policy* 38(1): 419–431.

The Government Office for Science (2014) The IoT: making the most of the Second Digital Revolution. *WordLink*: 1–40.

Toivonen M. (2004) *Expertise as Business. Long-Term Development and Future Prospects of Knowledge-Intensive Business Services (KIBS).* PhD Dissertation. Helsinki University of Technology.

Tranos E. (2013) *The geography of the Internet: cities, regions and Internet infrastructure in Europe*. Cheltenham, UK: Edward Elgar.

Tranos E. and Nijkamp P. (2013) The death of distance revisited: Cyber-place, physical and relational proximities. *Journal of Regional Science* 53(5): 855–873.

Tödtling F. and Trippl M. (2005) One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy* 34(8): 1203–1219.

Uzzi B. (1997) Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness. *Administrative Science Quarterly* 42(1): 35–67.

Vargo S.L. and Lusch R.F. (2008) Service-dominant logic: Continuing the evolution. *Journal of the Academy of Marketing Science* 36(1): 1–10.

Vermesan O., Friess P., Guillemin P., Gusmeroli S., Sundmaeker H., Bassi A., Jubert I.S., Mazura M., Harrison M., Eisenhauer M. and Doody, P. (2009) Internet of Things Strategic Research Roadmap. In: Vermesan O. and Friess P. (eds), *Internet of Things -Global Technological and Societal Trends*, Aalborg: River Publishers, 9–52.

Ward K. and Street C. (2012) Reliability. Mills A., Durepos G., and Wiebe E. (eds), *Encyclopedia of Case Study Research*, Thousand Oaks, CA: SAGE Publications, 801–802.

Webster F. (2014) *Theories of the Information Society*. London: Routledge.

Weiser M. (1991) The computer for the 21st century. *Scientific American (International Edition)* 265(3): 66–75.

Welch E.W. and Feeney M.K. (2014) Technology in government: How organizational culture mediates information and communication technology outcomes. *Government Information Quarterly* 31(4): 506–512.

William C. and Turner O.P. (2007) *The SAGE Handbook of Social Science Methodology Introduction*. Thousand Oaks, CA: SAGE Publications.

Williamson O.E. (1985) *The economic institutions of capitalism: firms, markets, relational contracting*. New York: Free Press.

Willis K.S. (2017) *Netspaces: Space and place in a networked world*. London: Routledge.

Wilson M.I. and Corey K.E. (2000) *Information Tectonics: Space, Place and Technology in an Electronic Age*. Chichester: Wiley.

Wilson M.I., Kellerman A. and Corey K.E. (2013) *Global information society: Technology, knowledge, and mobility*. Lanham: Rowman & Littlefield Publishers.

Windrum P. and García-Goñi M. (2008) A neo-Schumpeterian model of health services innovation. *Research Policy* 37(4): 649–672.

Witchalls C. and Chambers J. (2013) The Internet of Things Business Index: a quiet revolution gathers pace. *The Economist Intelligence Unit*: 1–32.

Wood P. (2005) A service-informed approach to regional innovation – or adaptation? *The Service Industries Journal* 25(4): 429–445.

Wortmann F. and Flüchter K. (2015) Internet of Things: Technology and Value Added. *Business and Information Systems Engineering* 57(3): 221–224.

Xu L.-D. (2015) *Enterprise integration and information architecture: a systems perspective on industrial information integration*. Boca Raton: CRC Press.

Yeung H.W.-C. (1997) Critical realism and realist research in human geography: a method or a philosophy in search of a method? *Progress in Human Geography* 21(1): 51–74.

Yeung H.W.-C. (2003) Practicing New Economic Geographies: A Methodological Examination. *Annals of the Association of American Geographers* 93(2): 442–462.

Yeung H.W.-C. (2005) Rethinking Relational Economic Geography. *Trans Inst Br Geogr NS* 30(1): 37–51.

Yin R.K. (2013) *Case Study Research: Design and Methods*. 5th Edition. Thousand Oaks, CA: SAGE Publications.

Yue A.R. (2012) Validity. Mills A, Durepos G., and Wiebe E. (eds), *Encyclopedia of Case Study Research*, Thousand Oaks, CA: SAGE Publications, 959–963.

Zaheer S. and Nachum L. (2011) Sense of place: From location resources to MNE locational capital. *Global Strategy Journal* 1(1–2): 96–108.

Ziegeldorf J.H., Morchon O.G. and Wehrle K. (2014) Privacy in the internet of things: Threats and challenges. *Security and Communication Networks* 7(12): 2728–2742.

Zook M. (2002) Grounded capital: venture financing and the geography of the Internet industry, 1994-2000. *Journal of Economic Geography* 2(2): 151–177.

Zook M. (2005) *The geography of the Internet industry : venture capital, dot-coms, and local knowledge*. Oxford: Blackwell.

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INTERNET OF THINGS IN SERVICE INNOVATION

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Abstract

Last decade has witnessed rapid growth of Internet of Things (IoT) literatures by scientists from technology domain such as computer science, telecommunication and engineering, but very few studies have been done by sociologists and even fewer by economic geographers in service research. The great impact that IoT will bring to service offerings and its spatial consequence is disproportionate to how much research has been done in this area. The paper aims to understand how the adoption of IoT affects the spatial ramification of service offerings and service business. After the theoretical framework and research method, part three explains what the implications of IoT in service context are, why and how IoT enables innovation in services and the current obstacles. Part four further discusses what could be the spatial ramification with the case of China emerging IoT industry in city Wuxi.

Keywords
service innovation, internet of things, economic geography, digital economy

JEL Classification
L86 - Information and Internet Services; Computer Software
L96 - Telecommunications
O33 - Technological Change: Choices and Consequences; Diffusion Processes

Introduction

Understanding the relationship between emerging information and communication technologies (ICT) and service activities is a constant job for service research (Bryson, Rubalcaba and Ström, 2012, p651; Daniels, 2012, p631) as the adoption of new technologies has been the driving force of innovation in services (Gago and Rubalcaba, 2007; Miles, 1993, 2006), which impacts the spatial ramification of service offerings and service business (Beyers, 2012, p665). Such imperative is reflected in the IBM global CEO study this year, which results that technologies factor (71%) is considered as the most critical external forces in the next 3-5 years, which is over people skills (69%), market factors (68%), macro-economic factors and globalization. CEOs saw technology inspiring entirely new industries and fundamentally disrupt others and mentioned the new possibilities driven by the physical world equipped with networked sensors (IBM, 2012, p13). Linking the physical world with networked technologies and equipped with networked sensors is the emerging technology revolution that some call “the Internet of Things” (IoT). IoT is much more than a technological revolution; it is also a social process. Think about how the internet has changed our daily life and work, and this is just the beginning. We are living in an increasingly connected and digitalized world, which is transforming how goods and services are produced. Ericsson (2012) predicts that by 2017 85% of the world’s population will have 3G internet coverage, while data traffic will grow from 2011 by 15 times. In 2010 the internet economy accounted for 4.1% of GDP ($2.3 trillion) in G-20 countries and by 2016 it will reach 4.2 trillion (Dean, et al, 2012). What makes it more striking is the growing interactive penetration between the cyber space and our physical world both in quantity and quality. Quantitatively it is between the years 2008-2009 when the number of connected devices exceeds the number of world population and by 2020 this number is estimated to reach 50 billion (CISCO, 2011; Ericsson, 2011, p3). Qualitatively many are not only connected but with sensing abilities to "feel" the condition and changes in its environment such as temperature, speed, body movement, lightness and so on. If internet is likened to brain, now it has started to have eyes, ears and hands. When billions of daily objects not only smart phones, TV or tablets, but everything such as lake, road, apple tree, shampoo, shoes, furniture and cars are connected in intelligent systems, it won't be hardly to believe that the IoT revolution, such quantitative and qualitative integration of the cyberspace and the physical world will dramatically change the world.

Last decade has witnessed rapid growth of IoT literatures by scientists from technology domain such as computer science, telecommunication and engineering, but very few studies have been done by sociologists and even fewer by economic geographers in service research[1]. The great impact that IoT will bring to service offerings and its spatial ramification is disproportionate compared with how much research has been done in this area. Such importance is two folds. One of the core values of deploying IoT infrastructure to connect the physical world sits in offering smarter and new services for individuals, communities and regions. Such extension of Internet from cyberspace to the physical world will inevitably deal with places: from the spatial forms of service business transforming to multi-agent frameworks, to the emerging service offerings for instance location-based service (LBS) which is enabled by embedded GPS sensors in connected devices. Considering the exponential growth of Internet services during the recent decades, the scope of change will be probably colossal. For example in China where IoT is anchored as one of the most important strategic high grounds in the world’s next economic and technical development trend by the country’s 12th Five Year Plan (MIIT, 2011), the market size of the industry is expected to top $117 billion by 2015 with 30% annual growth rate (CIT-CHINA, 2011). This figure represents more in China’s ambitious rather than the market size assumption. Actually at this early stage it is difficult to measure IoT’s potential

[1] Out of 1065 published items (including proceedings) under the topic “Internet of Things”, 167 papers are Internet of Things focused and most of them are in Computer Science (86 papers, 51%), Telecommunications (61, 36%) and Engineering (59, 35%), while there are only 2 papers from social science and 17 papers from Business Economics. Among those none-technology 19 papers, some of them are showing cases in emerging business opportunities, or tap its geographic impacts indirectly during the core discussion, but so far there has not been papers directly link Internet of Things, innovation in services and geography together from the result of this database. (Source: Web of Knowledge, by 2012-08-22)

market size as Michael Nelson, the former director of Internet Technology at IBM described "Trying to determine the market size of the Internet of Things is like trying to calculate the market for plastics, circa 1940. At that time, it was difficult to imagine that plastics could be in everything" (Valhouli, 2010, p3). Therefore studies in this domain are not only necessary but of great importance.

The paper aims to understand how the adoption of IoT impacts the spatial ramification of service offerings and service business. After the theoretical framework in part one and research method in part two, part three discusses what the implications of IoT in service context are, why and how IoT enables innovation in services and the current obstacles. Part four further discuss what could be the spatial ramification of IoT in services with the case of China emerging IoT industry in city Wuxi. In the end part five draws conclusion and future study implications.

1. Theoretical Framework

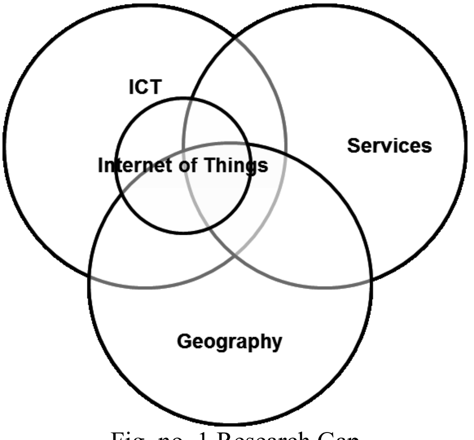

Fig. no. 1 Research Gap

Understanding how the adoption of IoT leads to spatial ramification of service offerings and service business is to understand the interconnections among IoT revolution of ICT, innovation in services and the changing geography. A large number of researches have been done in the interconnections between ICT and services, ICT/technological changes and geography, or geography of services (Kellerman, 2002; Davis and Heineke, 2003; Bryson, Daniels and Warf, 2004; Coe, Kelly, and Yeung, 2007; Mackinnon and Cumbers, 2007; Malecki and Moriset, 2008; Dicken, 2011; Beyers, 2012; Bryson, Rubalcaba and Ström, 2012; Daniels, 2012). For IoT, as the concept diffused across the globe, there has been a rapid growth of literatures from the technology domain (over 90% of the published papers focusing on IoT are in computer science, telecommunications and engineering: see footnote 1), global commercial players in promoting IoT (CISCO, 2011; Ericsson, 2011; IBM, 2012) as well as from international organizations and policies (ITU, 2005; US National Intelligence Council, 2008; European Commission CORDIS FP7; MIIT-China Academy of Telecommunication Research, 2011; CIT-CHINA, 2011). The research world of ICT, services, geography and the world of IoT so far have remained separate more than connected. However, the rise of IoT changes the ICT sphere, impacting the service offerings and geography of services. For example the world's leading IT services company believes that the world has become increasingly instrumented, more interconnected, and things more intelligent therefore smart infrastructure is becoming "the basis of competition between nations, regions and cities"[2]. Now we are standing on the blink of change and it is time to bridge this research gap (Fig. no. 1).

1.1 The Internet of Things

1.1.1 The rise of Internet of Things

In one decade, IoT has rapidly evolved from research centres to business communities, from disruptive technologies to national competitive strategies. Although the idea behind it has a long history, it is believed that the term "Internet of Things" was firstly introduced in 1999 by Kevin Ashton from the MIT Auto-ID Centre in a presentation about RFID and supply chain management innovation prepared for Procter&Gamble (Ashton, 2009). It was introduced by Technology Review (2003) among the 10 emerging technologies that would change the world. In year 2005 the trend was captured and pushed forward to a global scope by International Telecommunications Union (ITU). ITU launched a special report which has broadened the definition of IoT from disruptive technologies into an ecosystem of the future internet, predicting a new era in which "today's Internet (of data and people) gives way to tomorrow's Internet of Things".

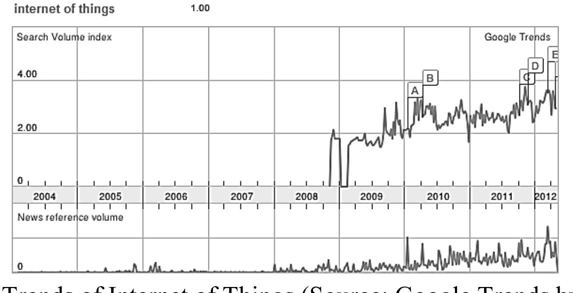

Fig. no. 2 Google Trends of Internet of Things (Source: Google Trends by May 8th 2012)

2008-2009 is the "big bang" of Internet of Things. The timing is revealed by Google Trends which shows the general public interest towards IoT starts late 2008 and since then has kept a steady increasing curve in search engines (Fig. no. 2). In September 2008, a new industrial alliance IPSO is formed by 25 members including Cisco, SAP and Sun. In the US, Internet of Things was regarded as one of the 6 Disruptive Civil Technologies with Potential Impacts on US Interests out to 2025 (the US National Intelligence Council, 2008). IBM launched Smarter Planet Strategy. In EU, the first international conference of Internet of Things was held in Zurich in March, followed by a series of reports and projects in EU FP7 such as Internet of Things Initiative (IoT-i), Internet-of-Things Architecture (IoT-A)

[2] The big idea was kicked off in November by IBM CEO Palmisano during a speech at the Council on Foreign Relations in New York City, which later became the differentiating competitive framework for IBM.

and European Research Cluster on the Internet of Things (IERC). In China the term Internet of Things caught the Prime Minister Wen Jiabao’s attention during a visit to Wuxi at east Jiangsu Province. He proposed an equation “Internet + Internet of Things = Wisdom of the Earth” and called for building the Sensing China centre. By the end of 2009, China R&D Centre for Internet of Things (CIT-China) was set up in city Wuxi with a joint force of Chinese Academy of Science and Jiangsu province. Since then the consortium of IoT industry in China has rapidly grown to the major cities and regions.

The emergence of IoT is a both global and local phenomenon. On one hand is the knowledge and technological trend which diffuse rapidly across the globe and are pushed forward by global players such as international organizations (ITU) and multinational companies (IPSO), while on the other hand is the diverged way of landing in different geographical contexts. Once integrated at a place, the development trajectory differs according to the cultural, economic and institutional patterns. For example, comparing with the EU bottom-up market driven tradition, the aggressive actions driven by the Chinese government on creating IoT industry has a top-down pattern with the government acting as the initiator, investor, regulator and major player. In the U.S. the term is more scattered into different application fields such as smart health, smart grid, smart logistics and smart food. Therefore it is fair to say that this global trend is implemented differently in varied places.

1.1.2 IoT as new dimensions of ICT: definition, key components and IoT services

There has been so far no universally accepted definition of IoT, but the key components are able to identify. The IoT definitions given by official documents although varied from different resources can shed lights on its key components. Here I am using the definitions from MIIT of China (MIIT, 2011, p2) and IERC to abstract the core components of an IoT system. The reason to choose them is that on the national level of China and transnational level of EU, the term IoT is widely accepted and promoted.

“IoT is the extended applications and extension of communication network and the Internet, which uses sensing technology and embedded intelligence to sense and identify the physical world. It is interconnected through the network transmission, by calculating, processing, and knowledge mining to enable information exchange and seamless links between people and things or things to things, so that real-time control, accurate management and scientific decision-making of the physical world can be realized”. (Author translated it into English from MIIT 2011 China IoT White Paper)

“IoT is an integrated part of Future Internet and could be defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network”. (Europe Research Cluster on IoT)

These two definitions although differed in terms and emphasises, show the key components of IoT system. It is the things embedded with sensors in physical world being seamlessly connected to information network, so that we have dynamic information exchange between people and things and between things and things. This implies the communication is based on information network, information flows from end to end, and the whole process requires information processing. The same as the other ICT systems, in the end it is the application of such information exchange (such as real-time control, accurate management and scientific decision-making) counts for the value of IoT system. Therefore information network infrastructure, connected things with embedded sensors, information processing capabilities and the applications are the four major components.

The new dimensions IoT brings to information and communication are:
1) Information: The information provider is extended from today's only computer and people to things in the physical world. Smart phones, TV and tablets have already connected to the internet world, becoming both the information receivers and providers. In the IoT vision, anything should be able to connect to the cyberspace with its own IP address. Therefore things in the physical world can actively provide information about itself or changes in its environment to the cyberspace as well as receive information from the cyberspace.
2) Communication: By adding things to the communication network of today's people-computer-people, it enables information exchange between people and things and between things and things (M2M).

The impacts on services are two kinds: the creation of new applications and the upgrading of related ICT services. MIIT (2011, p9) defined four categories of IoT services: 1) IoT applications (such as public services and industry-based services); 2) IoT infra-structure services (such as cloud computing, data storage, data centre, infrastructure components services); 3) IoT software development and system integration (such as system integration, software development, software services, intelligent information processing); 4) IoT network services (such as M2M information and communication services, industry-based ICT network services).

1.2 ICT and changing geography of services

ICT and other space shrinking technologies have brought great flexibilities for business activities to locate where they can benefit the most from reducing the transaction cost and from economic externalities (Coe, Kelly&Yeung, 2007, pp150). As a result it is changing the global service division of labour. The second trend, which is partially enabled by the first, is in the transformation of conceptualising service as co-production between a client and a service provider to the multi-agent frameworks of a plurality of providers, suppliers and varied agents interacting and coopetition with each other. This is defined by Bryson, Rubalcaba,and Ström (2012, p651) as one of the challenges drives service research in the next decade. For example in social network services such as facebook, twitter and weibo, users are both the content creators and consumers. Similar complex network trajectory can be captured generally in how innovation has been organized. Dodgson and Gann (2010, pp117) summarized innovation activities have been evolved from 18th century individual entrepreneurs to the 19th century formal research organizations and mid to late 20th century large corporation R&D departments to the nowadays multi-contributors in distributed networks of innovators facilitated by new ICTs. Consequently services processes are simultaneously more footloose and more agglomerated (Daniels, 2012, p631). The changing geography of services is part of the transformation of world economy.
Dicken (2011, pp6) pointed that the world economy has been qualitatively transformed in the nature and degree of interconnections, as well as in the speed with which such

connectivity occurs, including both a stretching and an intensification of economic relationships. One of the key driving forces is the changing forms, speed and interactive ways of information enabled by ICT. This change contributes to the acceleration of complex globalization process and globalization in turn "determines the acceleration of international circulation of ideas and information (said by Joseph E. Stiglitz, quoted in Androniceanu and Drăgulănescu, 2012, p367)." Consequently innovation activities and dissemination of innovation are increasingly condensed (Plumb and Zamfir, 2009, p379). A growing digitalized and connected world leads to the changing geographies of production, distribution and consumption of goods and services. For innovation in services, new technologies from the microelectronics revolution since 1970s till the tipping point of computerised technologies in the process of production, has resulted rounds of innovations which thoroughly reshaped how we live, work, move and entertain (Bryson, Daniels and Warf, 2004,pp157).

1.3 Information economic geography

Previous research shows that geography matters for information economy (Kellerman. 2002, pp1), and digitalization has not created a completely footloose economy, rather it contributes to the distortion of economic space resulting in both convergences and divergences from micro to macro scale of individuals, communities and regions (Malecki &Moriset, 2008, pp219). This character is proved by the geography of information infrastructure, which is neither decentralized nor concentrated but rather complex (Kellerman, 2002, pp21). The economic geography of information can be understood in three aspects:

1) Information as a commodity

Kellerman (2002) assumes that information per se is similar to other commodity with production, processing, transmission and consumption prices and the prices are varied at different places. Information always exists and being created all the time, the differences lie at how much useful information we can capture and utilise it. Information is not a consequence of technology; rather it existed long before ICT (for instance culture as information). What technologies have changed are the scale and forms of information, how we produce, store, transmit and consume information, the speed of processing information and the channels where such interactions occur. Electronic and information age has brought us all kinds of gadgets to produce, disseminate and exchange information such as telephones, faxes, TVs, Walkman, CDs, digital cameras and computers, which are facilitated by telecom networks and later the Internet. Such changes have leaded the rise of information society and information has increasingly become a commodity in its own right (Kellerman, 2002, pp14).

2) Information both has and do not has a location

Information in its abstract form does not occupy space, but the producing, transmission and consumption of information are dependent on "containers" which usually occupy locations. The most common containers are humans. The transmission process is highly dependent on network infrastructure which is unevenly developed in the world. Similar to other products, the consumption and dissemination of information and knowledge differ from place to place, which relates to contextuality such as language, culture, education, economic condition and so on(Kellerman, 2002, pp9). Therefore seemingly placeless information commodity is dealing with location all the time.

3) Information, knowledge and innovation

The mechanism linking data, information and knowledge to innovation is explained by Kellerman in the information sequence (Fig. no. 3). He pointed out that information in nature is transformative, communicative and follows four basic sequential processes:
a) Data to information by meaningful patterns and context;
b) Information yields information by interaction for instance between people speaking or writing;
c) Information to knowledge by its application. But knowledge also produces information and as Roberts (2000) pointed out that knowledge is required for the additional development of information;
d) Tacit knowledge, codified knowledge and information are the basis of Innovation and innovation creates new information and information technology.

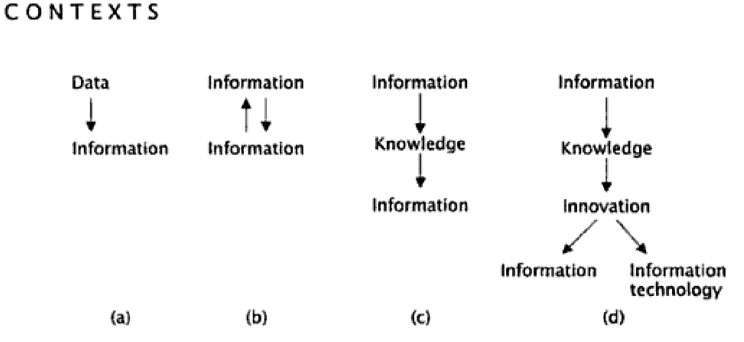

Fig. no. 3 Sources: Kellerman (2002) The Internet on Earth: A Geography of Information. pp4

If geography matters for information, then it matters even more for knowledge and innovation. Although ICT and business globalization explicit knowledge more universally accessible, implicit knowledge is still spatially sticky (Asheim and Gertler, 2005; Cooke, 2008), which leads knowledge-intensive economic activities to be more geographically clustered. However, it is wrong to equal implicit knowledge to local and explicit knowledge to global, because both of them can be exchanged from local to global (Bathelt, et.al, 2004, p32). These distinction of knowledge builds the foundation of space and place relating to knowledge/technology diffusion, which makes place (innovative milieu) where a specific social-technological context embedded, an important factor of knowledge creation and this specific context usually includes three aspects (Dicken, 2011, pp104):
1) Economic, social, political institutions
2) Knowledge and knowledge of know-how which evolved over time in a specific context
3) Local buzz: take-for-granted conversations between partners in different kinds of relations defined by uncertainty.

To sum up, these three aspects of information explain the current characteristic of spatial implications of ICT, which is not to eliminate geography but rather redefine geography, causing new networks of centrality and peripherality (Li et al, 2001; Moss and Townsend 2000; Graham and Marvin, 2001). Kellerman (2002, pp21-22) argues that this process may imply the evolution of urban specialization of information economy into two lines. First is the phase in the handling of information from production to consumption. The second lies at the types of information production in general, which includes information, knowledge and innovation. A city which specializes in more than one phases within any of the two lines, will become a leader in information economy.

1.4 The economics and creativity of networks: Metcalfe's Law and Cantor's theorem

Why a future with 50 billion or more connected devices is so exiting for CISCO and Ericsson, or why CEOs see the new possibilities driven by the physical world equipped with networked sensors from IBM's survey? This relates the power and creativity of networks. The uniqueness of information which is not similar to other material products is its re-production almost cost nothing (for instance once a computer game is created, the mass production of the software is very fast and cheap). Gilder (1993) named it the law of increasing returns: Usually when people share a piece of equipment, the return diminishes; when more people are engaged in the network, more value is returned to the users. Ideas and knowledge follow the law of increasing returns, which indicates economic value can be created from non-material resources.

Metcalfe's law is often used to explain the power and economic value of a network increases exponentially by the number of nodes connected to it (Shapiro and Varian, 1998, pp184). George Gilder (1993) applied Metcalfe’s observation to Metcalfe’s Law as "connect any number, ‘n’ of machines whether computers, phones or even cars - and you get ‘n’ squared potential value." The mathematical foundation is the number of potential interconnections between two nodes in a network. Therefore by equalling the total value to its potential interconnections of a network that consists of n nodes, the value of a network is:

$$V(n)= n*(n-1)/2 \ (n=N)$$

V(n): the value of a network with n nodes

The economic implications of such network effect are striking in two aspects. One is the nature of network effect, and the other is the exponential pattern of growth: since the potentially N square value, Metcalfe’s law is initially used to explain the exponentially growth of the Internet and social network. In fact the growth patterns of network value are many which varied by how to define value. Tongia and Wilson (2007, 5) summarized a list of such patterns to specify the value of a network based on the number of people or nodes connected. They found all of them show monotonically increasing value with growth ranging from linear to factorial: N (Sarnoff), N log (Odlyzko), Nc (Nivi), 2n (Reed) and N! (Haque).

Cantor's theorem is named after German mathematician Georg Cantor who first proved it, which states that for any set A, the set of all subsets has a strictly greater number of

elements than A itself. Ogle (2007, pp118-119) used the principle to indicate that "there are always more sets of things than things…relationship between groups of things (some real, some arbitrary) are spontaneously generated". A set is a collection of things sharing common property. Ogle used a set defined as married men as an example. The set of married men is large, but the subsets it contains are even larger such as those who like baseball, who vote for Ralph Nader and those who own SUV and the list is endless. Combined with Metcalfe's Law, it also suggests that by adding one thing into a set immediately creates a multitude of subsets, and these spontaneous emergences of relationships give rise to new meaningful patterns. Cantor's theorem shows the mathematical necessity of subsets outnumbering the members of a set, while in reality the value of meaningful patterns of those subsets depend on where, when, how, and to whom.
The economic implications of such new meaningful patterns hint that 1) there is a value underlying because if we say something is meaningful then it has a value no matter if it is material, practical, emotional or spiritual value and 2) "new" signals creativity and innovation. The essential point is that both of them can be generated spontaneously from a dynamic network, which makes a dynamic network as a magic field of economic externalities.

2. Research methods

This paper draws empirical analysis based on data gathered from desktop research and field trips in China.

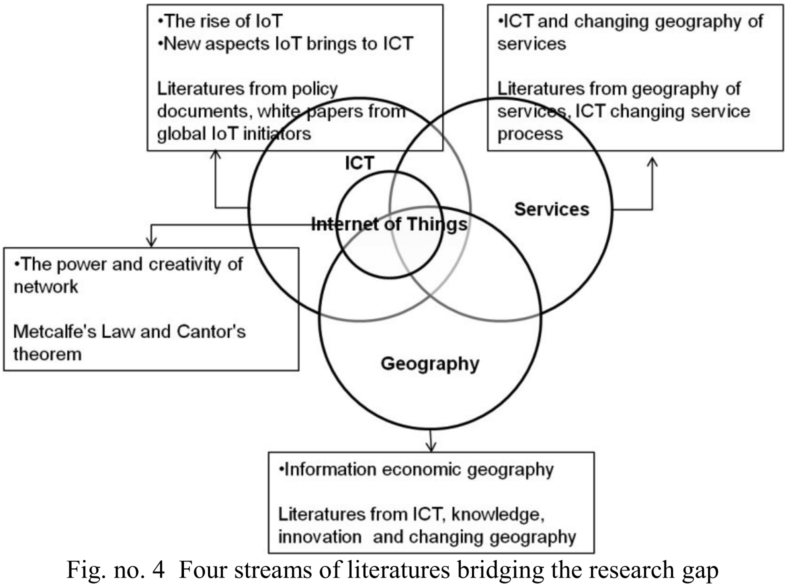

Fig. no. 4 Four streams of literatures bridging the research gap

In the theory aspect, the paper aims to fill in the research gap of IoT (as a revolution of ICT) impacts to spatial ramification of service offerings and service business. The previous studies are either focused on the relations among ICT-services-geography, or purely IoT in technology and policy domains. Therefore a desktop research to combine literatures from different streams of studies is necessary to build the theoretical framework. Four streams of literatures are explained to bridge the research gap identified in the beginning of part two (Fig. no. 4).

In the practice aspect, I conducted field trips to China during April 2012. Field trips are in two places: 1) the 2nd Expo of Internet of Things Technology and Application in Suzhou China and 2) the National IoT R&D Center at Wuxi, China. For the visit to the IoT R&D center in Wuxi, I interviewed with people working in or facilitating IoT industry about their thoughts, experiences and concerns of applying it into practice. For the Expo in Suzhou, the main task is to gather the latest IoT applications tapping emerging service offerings.
People who I have interviewed are:

- Miss Jing Wen and Deputy Direct OuWen from CIT-China at Wuxi,
- Ph.D Guanxi Yin: former Vice President of Wireless Sensing Network, Wuxi China
- Miss Da Yin and Dr. Xiang Wang: Shanghai Institute of Microsystem and Information Technology Wireless Sensor Network of China Academy of Science
- Mr. Yanlin Ren: IBM Shanghai

The new dimensions of IoT brings to ICT is discussed in theoretical framework. Based on the information and knowledge from desktop research and field trips, the implications of IoT in service innovation and the geographical impact are discussed in the following arts.

3. IoT in service innovation context

3.1 Linking theories to the definition of IoT in service context

The challenge of defining IoT in service context is actually in the lacking of a unified definition of IoT itself. This leads to two implications. One is although the fuzz of IoT definition causes terminology problem, it is not necessary to give a definition for the sake of definition, if defining will narrow the potentials of its applications. The other is in fact it might be easier to define IoT in a certain context (for instance the services) than to abstract one general definition to fit all. Therefore the definition can be summarized by answering two questions: 1) what is the value of linking cyberspace into the things of physical world in service context? 2) What are the key components of IoT system?

The first question can be explained by the network effect. As we know from the economics of network: the power and economic value of a network increases by the number of nodes connected to it and such growth could be exponential; The law of increasing returns: usually when people share a piece of equipment, the return diminishes; when more people are engaged in the network, more value is returned to the user. Moore's law provides the possibility that computers can be integrated in a wider range of applications on devices from a gigantic bridge to a tiny button. Having both the incentives and abilities to connect more, it appears the possibility of the next round exponential growth. The rise of social network such as facebook, twitter, google+, and weibo is an example of network effects by connecting people. Therefore what will happen if we connect the things? The value of connecting things is the value it can bring back to people. In the service innovation context, information plays a key role. Some services are in forms of information such as software, data mining, business consulting, financial services, public information in city management, and more are facilitating for new and better services, as Richard Barras pointed in many ways the information technology revolution was an "industrial revolution" in the service sectors (Miles, 2006, p440). The four categories MIIT defined as IoT services are either providing new applications (services) or upgrading existing ICT related services. Therefore the value of connecting things in service context in general is providing useful information and valued services.

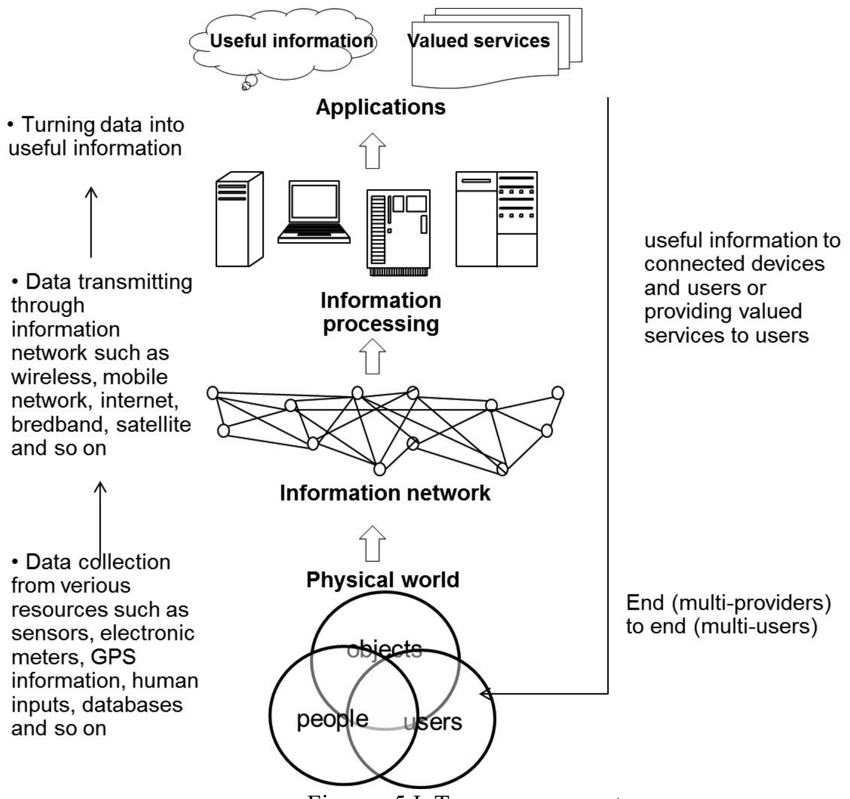

Fig. no. 5 IoT core components

The second question is already discussed in part two, and they are information network infrastructure, connected things with embedded sensors, information processing capabilities and the applications. Therefore in the service context, IoT can be defined as a dynamic end to end information network seamlessly linking physical and cyber space by which data from objects are connected, interacting and processed to enable people, objects and systems turning data into useful information and valued services to the users. It contains at least four core processes (see Fig. no. 5). By doing so, we can connect the physical objects integrated in the cyber space, which is a bit like providing a "nerve" system into the physical world.

3.2 Why and how IoT enables service innovation

3.2.1 Information Sequence Loop

An obvious feature of IoT is capacity in connections of objects, time and place. The next generation internet Protocol (IPv6) which formally launched in June 2012 globally is able to provide every connected object with identifiable and addressable address because of its immense capacity[3]. Objects cannot talk. To make them “talk” we need sensor imbedded intelligence to enable objects to monitor the change in environment such as temperature, moisture, movement and pressure. Miniature nanotechnologies make it possible to insert sensor on almost anything from a gigantic bridge to a little button (ITU, 2005). The global diffusion of wireless, 3G/4G mobile network, and broadband forms a networked global information high way to increase the mobility (anyplace) and flexibility (anytime) of such connection. The immense capacity in connected objects (heterogeneity), time and place (scalability) offers a new horizon for services to realise its potential.

Capacity in size, time and place means IoT infrastructure greatly extends the selections of resources from which we can capture data. Capturing more data to transform into useful information and valued services opens new grand for innovation. Baudrillard (1990, pp219) said: “Information can tell us everything. It has all the answers. But they are answers to questions we have not asked, and which doubtless don’t even arise”. While Brackett (1892) argued do not seek for information that you cannot make use of. Perhaps both of them are right and IoT will extend the first and narrow down the second. The mechanism linking information to innovation is explained by Kellerman (2002, pp2-7) in the information sequence. Based on Kellerman’s analysis, I would like to add a 5th process that is information technologies enhance the collection of data, optimize its transformation to useful information and hence helps the generating of knowledge and innovation. In other words, information technologies optimize the earlier four processes and turn the information sequence in to a loop of sequence. Therefore based on Kellerman’s version, I illustrated my interpretation of the information sequence loop as in fig. no. 6.

For example IoT is applied in Taihu Lake at Wuxi China to overcome the shortcomings of acquiring data for algal bloom forecast system. Taihu Lake is the 3rd largest lake in China and the most important source of drinking water supply for cities around. The lake suffered from complex nutrient and chemical pollution and in 2007 the progress of algal in the lake jammed the water plant’s intake and caused water supply incident. Traditionally the accuracy rate to predict a blue algal bloom is low due to two reasons: the formation of algal is complex and uncertain; the monitoring is lacking of synchronization and continuity. By applying IoT to build a three layered system, the new platform achieves an overall accuracy of 80% in forecasting blue-green algal blooms (Yang, et al, 2011). The new forecasting system can’t direct fix the algal bloom, but by monitoring the formation of algal, more data can be collected and analyzed to help experts finding treatments. By providing more accurate forecast, people can be more proactive, preventing it jamming the intake of the

[3] The IP protocol using now is 32 bits IPv4 which has total 322 (4.29 billion) addresses. IPv6 is 128 bits which means theoretically it can provide 1282 (3.4×1038) addresses. The earth is 5.98×1027 grams, and it means every gram on earth will get almost 5.7×1010 addresses.

water plant. By more information to the public about the condition of blue green algal in Taihu Lake, we can increase the public awareness of the quality of water.

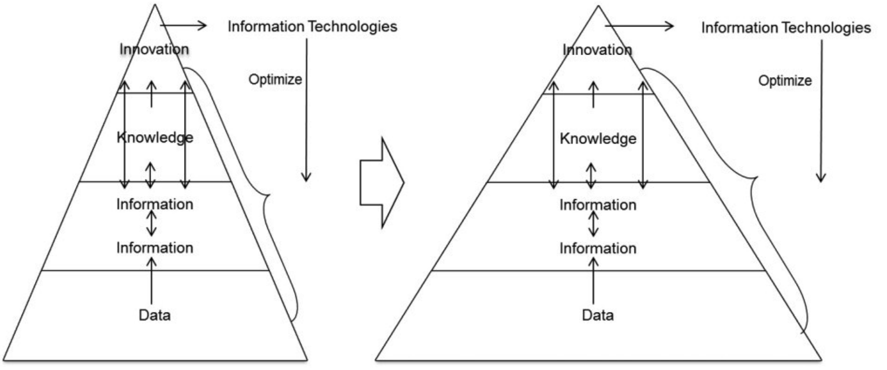

Fig. no. 6 Information Sequence Loop, which is developed from Kellerman's information sequence (2002, pp4)

3.2.2 Smart

Smart is a core feature. "Smart" things/services such as smart buildings, smart health, smart grid, smart transportation, smart city and the most common one smart phone are frequently mentioned in the ambitions of IoT vision. Despite the preference in marketing, the word "smart" is ambiguous: how smart is smart? Does it mean IoT enables things to think and act like humans? ITU (2005) explained smart as implying a certain processing power and reaction to external stimuli. I would argue that smart is a relative concept and it is by implying IoT, objects and systems are provided new abilities to create values that they previously cannot. Therefore it is a context based services. By connecting things in different contexts, we can create new services. It can be explained by Cantor's theorem which claims new meaningful patterns can be generated spontaneously in a dynamic network. For instance Echelon Corporation helped the city of Oslo in Norway to launch a pilot E-street lighting system. The pilot project connected 120 individual street and roadway lights installed with sensors into a smart network. The sensors can measure the degree of lighting around and the traffic volume, collect these data and send back to the central management site through ELON's internet edge server. The central management site can remote control each street light's lighting status based on the weather (raining, sunny), traffic volume (demand-based) and time of the day (daytime or night). As a result we see a smart street light which knows when to be off, when to be on, and how much brightness is needed.

Smart can be realized through automation and telematics. The value of making things "smart" is to enable them provide smart services. Telematics enables remote control, which creates a kind of "wormhole effect" to overcome the spatial distance. The power of innovation in services has been underestimated historically (Sheehan, 2006). Such bias is partly explained by the interactivity (services are customized according to client needs) and simultaneity (producing and consumption of services often happen at the same time) nature, which constrain services in "small scale" and "local basis" (Miles, 2006, p437).Telematics is like our hands direct operate a connected device far away through a “wormhole”. Such wormhole effect enables real-time control. For example remote printing allows people to print documents at office from home. Remote medical system make surgeons to operate from another place and in the future you may water your home flowers from a beach in vacation. Automation usually means without human intervention when it works (but still needs people to design, maintain and improve the system). Automation in IoT vision aims to offer smart, personalized services as it is complex events-based. For instance High-end fashion brand Prada tags Texas Instruments chips to their clothing and accessories at their boutique in Soho district New York, so that when clients hang over the products they want to buy into the dressing room, a flat panel TV is activated to play the models wearing those selected clothing with tips of accessories by designer Miuccia Prada (Schoenberger and Upbin, 2002).

3.3 Obstacles

For deploying IoT in service innovation, there are as many obstacles as the benefits. Generally speaking, diffusion of any technology revolution requires standardization and interoperability while information security and privacy protection are trickier to handle since they are not only technological problem but have legal and social concern (Schoenberger et al, 2002; ITU, 2005; Commission of the European Communities, 2009; MIIT, 2011). A set of IoT standards is the first step of implementing IoT in various applications from hardware, software to services. Standards can also be used as trade barriers to prevent foreign companies entering the domestic market, therefore standardization takes time and it is a negotiation process among industry, national regional entities and international associations. Two implications can be summed up: standardization is crucial to IoT development to mass diffusion and it will take time. Most of the current IoT cases are realized based on independent systems, which are not really able to communicate with objects outside of their own “islands”. Because of the lack of standards, smart objects have not been able to connect and communicate freely in the global network at a large scale. Security standard is also part of the standardization of IoT. It is considered as one of the most importance IoT governance task in almost all countries and regions. Without a safe information environment, IoT will not able to fulfil its potential in contributing to economic growth and social progress.

Protection of privacy is a complex legal social problem in information society (ITU, 2005). Basically it relates to the paradox of information sharing and control. The IoT action plan in EU (2009) action3 suggested to launch a debate on the technical and legal aspects of the ‘right to silence of the chips’ to make sure that individuals should be able to disconnect from their networked environment at any time. But even the control button of connecting to the network or not is in the hand of users, without a secure network environment, these private information can be at risk by hackers and system error. Considering how complex and pervasive that IoT system can be, all those concerns will be crucial obstacles for its development

Digital identity is controversial. On one hand smart objects with self-configuration and virtual identity are able to actively participant in the business and social process, which contributes to valued services by autonomous activities with less or no human interventions; on the other hand, when 50 billion or even more such smart objects are participating in social activities, it changes the proportion of "us" and "objects" in the constitution of human society. It could be disruptive to the human-cantered way of perception of the world that we used to hold. Do we want to live in a world that machines make decisions for us? These concerns will prevent the public acceptance on the development of advanced IoT services.

Limitation of sensor technology, network availability and quality as well as the information processing capabilities are also constrains of implementing IoT in service innovation. In practice, industrial barrier is preventing the smart objects connectivity and information sharing cross existing segment boundaries. IoT services will remain more “local” in both geographic perspective and business segment perspective for a considerable period of time because it takes time to reach global standards and even after that it will take longer time to solve privacy concern. The digital identity issue differs in varied culture and social contexts. Limitations on sensor technology, network infrastructure and information mining ability differ as well in different cities, regions and countries. Therefore the obstacles of IoT services imply that its development patterns are varied in different places.

4. Impacts of spatial ramifications

4.1 Spatial dimensions of IoT

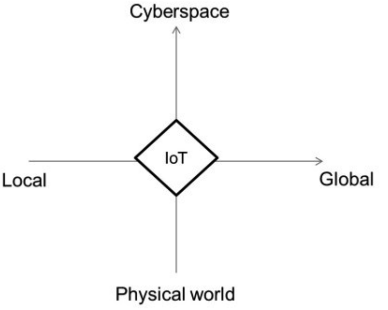

Fig. no. 7 the spatial dimensions of IoT

If geography matters for the internet, geography matters more for IoT. It is where local meets global and where the cyberspace and physical world interwoven (fig. no. 7). IoT service activities are place-rooted with complex local, global agents’ frameworks.

For agents in IoT, the end to end flow shows that there are multiple data providers, multiple data processors and multiple users. Some users are also the data providers. Some services are automatically generated by information exchange; many are developed by specialised service providers. Therefore the co- production and consumption of services are becoming multi-agent frameworks. In a technological perspective, “space shrinking” technologies such as transportation and communication technologies which should have declared the death of geography by reducing the time-space constrains (O’Brien, 1992), in reality hasn’t. Even in the ubiquitous Internet world, there are full of spatial inequalities (Coe, Kelly, & Yeung, 2007, pp125-148). This paradox characterizes the contemporary economy, which I would argue that the presupposition of such paradox is incomplete. It might be because that how we name them (ubiquitous and space shrinking) are misleading our understanding of their spatial consequences. They do enable information and digital goods/services to travel around the globe in blink of an eye, while at the same time make information and digital goods/service much easier to concentrate at certain places. Therefore this geographic convergence and divergence is two sides of the same coin: either being footloose or agglomerated is up to how the economic activities are organized. Companies evolve through interactions with others from local to global environment, throughout the whole value chain as well as with their consumers, strategic partners and even competitors, and they constantly adjust location strategies by maximizing benefits from such dynamic local and global network to reduce the transaction cost and benefit from the economic externalities. Therefore IoT service activities are place-rooted with complex local, global agents' frameworks.

For IoT services, as it is a synthesis of information, things and users in the physical world, geography naturally plays a key role because even the information processing and storage can be footloose, the things from which data are collected and users will always have a geographic context. The value of such services is also context based: it relates to when, where, what, how and to whom. Especially in the current phase of IoT system, the majorities are local based. For instance the Shanghai city intelligent transportation system, data are locally collected, locally processed and locally consumed. The on-going construction of smart grid system is more on a national level in terms of management and investment but still it comes down to every electric meter. With the breakthrough in international IoT standards, it might be that in the future various connected devices and things are more or less universally communicating with each other like today's smart phones, tablets and TV, but still users in different geographic contexts are varied in services valuation and these services are strongly connected to local telecom operators. Moreover for those concerning critical social infrastructures for instance the smart grids for the power supply and some applications require handling private data like patients information in smart health, it also involves governments and authorities. Inevitably the "local" factor takes a crucial role.

4.2 The case of China emerging IoT industry: City Wuxi

IoT came into the public view at full blast in China after Prime Minister Wen Jiabao's visit to the CAS Wuxi. Since then city Wuxi has become one of the leading promoters in IoT industry. In less than 4 years, Sensing China Centre and National IoT R&D centres have been built with joint force of Wuxi government and CAS, as well as the formation of National Sensor Network Innovation Demonstration Zone where by mid-2012 over 600 companies related to IoT industry with annual sales volume over CNY 1 million. In year 2010 and 2011 the IoT industry of Wuxi reached a growth rate at 16.9% and 25.8%[4]. In this part, city Wuxi and its fast growing IoT industry are discussed in both the aspect of "local context" (location, social-economic-political institutions, capital, labour) as well as the aspect of information handling and types.

[4] Statistical data of city Wuxi on the 2009-2011 National Economic and Social Development. [online] Available at:< http://www.wxtj.gov.cn/tjxx/tjgb/index.shtml> [Accessed 20 July 2012].

4.2.1 Local context[5]

The Chinese government in this case as usual is the initiator and core player in creating the IoT industry. Prime Minister Wen Jiabao's visit to Wuxi in 2009 is the trigger. Mr. Guanxi Yin is the former Vice President of Wireless Sensing Network which is also known as the centre of Sensing China. The centre is located at a modern twin building in Wuxi national software park (iPark). During my interview he said the centre was set up right after Prime Minister's visit, as a response to his call for building the Sensing China centre. The government of Wuxi in this case took quick action and made big efforts to be the first. Da Yin from CAS Shanghai told me that CAS institutes have been working on IoT project, although not named as IoT quietly for many years in Shanghai, Jiaxing, Wuxi and other offices but have not attracted the government's attention. So in that sense Wuxi is lucky, however Wuxi cannot be successful without its own merit.

City Wuxi is located in the east Jiangsu province within the core of Yangzi Delta economic zone, with less than one hour by train to Shanghai. The city has enjoyed fast economic growth for decades, with annual GDP growth around 11%-13% even after 2008. 2011 GDP per capita reaches $18000, and the tertiary sector shares 44% (primary sector 1.8% and secondary sector 54.2%). Therefore it is a city which is in transitional period towards tertiary civilization. As in developing countries the growth of tertiary sector is crucial to cities and regions going through structural change (Malecki and Moriset, 2008), the city is actively looking for new growth opportunities for sustainable development especially after the 2008 financial crisis. It is one of the leading cities in software industry and service outsourcing, which increased over 33% last year, and 44% in year 2010. Microsystem and Information Technology industry increased over 16.7% in 2010 and 15.1% in 2011. The Wuxi national software park (iPark) started from 2007 and is a combination of creative industry and software industry especially in service outsourcing with over 500 international and local companies. It is also co-locating with the National Sensor Network Innovation Demonstration Zone. Therefore city Wuxi has the motivation and capability to promote IoT industry.

By acting fast, it is able to attract national and regional resources to strengthen the first mover advantage. For instance the China R&D Centre for IoT is built at Wuxi aiming to build up a platform for linking public authorities, R&D institutions, companies and start-ups with investors and public funding. The centre has gathered around 700 specialists (many of them are from other parts of the country and abroad) with 15 million US dollars registered capital and 78-157 million US dollars start-ups funding. By 2012, the network has expanded to 13 research institutes, 10 universities, 4 investment companies and other local members from public and private sectors. Over 10 start-ups have been incubated. The development plan till 2020 of Wuxi National Sensor Network Innovation Demonstration Zone got approval from the State Council which often means it is able to get direct support and resources from the national level. Therefore the founding of National IoT R&D Centre enables the city to attract talents and resources from a national and global scope, which in turn strengthens the capability of the city to develop IoT industry.

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[5] The statistics of the city Wuxi is from the same source as footnote 4. The information about the China R&D Centre is collected from interviews and the field trip.

4.2.2 Information handling and types

Software, service outsourcing and Microsystem and Information Technology industry have been Wuxi's competitive edge in service sector. So the city is strong in information production, which also builds the basis of IoT services from IoT software development and system integration. However, as mentioned by Deputy Direct OuWen of CIT-CHINA, the biggest challenge ahead is to build the industrial value chain, to attract the market and companies from private sectors to join the business. At the current stage, many IoT projects are government funded, and the intention is to show examples to the market, so that in the end more companies and invests from private sectors can join and build the industrial value chain. Therefore, the phase of consumption is not yet achieved.

In terms of types of information, the creation of information, knowledge and innovation are intensively clustered in Wuxi and the resources are from local, national and global levels. During my visit there, I found they also educate IoT related PhD students based on the resources from CAS. Many of the 700 employees of CIT-China are from other parts of China, and with international background. 13 research institutes from CAS participating in the founding of the centre are from other parts of China. The main task for the centre is achieving more Independent Intellectual Property in technological innovation of IoT system.

From the case of Wuxi, we see a very strong government lead combined with the national will, local anxiety to meet the challenge of structural change and industrial upgrading. The realization of such ambition is also supported by geographical advantage (one of the core cities in the network of Yangzi Delta economic zone and the 1 hour network circle to the world's city Shanghai), local advantage as a leading city in terms of software and service outsourcing and the first mover advantage. The future is full of opportunities and challenges. The government push model is not sustainable. It must be followed by the fast adoption in industry and the creation of business model. Although we see some emerging patterns in division of labour among the members of current consortium, the competition from other cities and regions will increase in terms of national funding, R&D investment and with more local, national and international players join the IoT fest, the map of China's emerging IoT industry will keep on changing.

Conclusions

The capacity and smart characteristics of IoT enables innovation in services by 1) enlarging the data collection from human centered to the human-nonhuman network and 2) offering smart services realized by telematics and automation from varied embedded networked sensors. The future of more than 50 billion connected objects excites us from the perspective of economics of network and spontaneous generation of new patterns from a dynamic network. Information builds the foundation of innovation and the change of where and how we collect exchange and utilize information builds the competitiveness of the future. The IoT vision linking the physical world with cyberspace will fundamentally change the rules of the game and we are standing on this brink of change. Local factor plays an important role in IoT services from investing, organizing, and evaluating to executing and the current obstacles push such local factor further. IoT service activities are place-rooted with complex local, global agents' frameworks. The case of China's emerging

IoT industry shows how much the local factors play in the course of creating China's IoT industry. With more players from local, national and international level joining in this fest and the evolving of industrial value chain, we shall foresee the increasing competition and complexity, which will continue to change the map of IoT services. Therefore, more research in both theories and empirical cases should be done to better understand its consequences in spatial patterns.

References/Bibliography

Androniceanu, A., Drăgulănescu, I., V., 2012. Sustainability of the Organizational Changes in the Context of Global Economic Crisis. *Amfiteatru Economic.* Vol: XIV, No. 32, p365-379.

Asheim, B. T., and Gertler, M., 2005. The Geography of Innovation: Regional Innovation Systems. In: J. Fagerberg, D. Mowery and R. Nelson, ed. *the Oxford Handbook of Innovation*. Oxford: Oxford University Press, pp. 291-317.

Ashton, K., 2009. That "Internet of Things" Thing. *RFID Journal*. [online] Available at:< http://www.rfidjournal.com/article/view/4986> [Accessed 20 April 2012].

Bathelt, H., et.al, 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, vol 28, 1, 31-56.

Baudrillard, J., 1990. *Cool Memories*, Verso.

Baumann, M., 2010. Google Joins Movement for 'Internet of Things'. *Econtent*, 33(2), 12.

Beyers, W.B., 2012. The service industry research imperative. *The Service Industries Journal*, 32:4, p657-682.

Brackett, A.C., 1892. The *Technique of Rest*. Harper and brothers.

Bryson, J., Rubalcaba, L., Ström, P., 2012. Services, innovation, employment and organisation: research gaps and challenges for the next decade. *The Service Industrial Journal*, 32:4, p641-655.

Bryson, J., Daniels, P., Warf, B., 2004. *Service Worlds People, Organizations, Technologies*. Routledge.

CISCO (2011) The Internet of Things: How the Next Evolution of the Internet is changing everything. *Cisco Internet Business Solutions Group (IBSG) White Paper*.

CIT-China.2011. *China IoT industry blue book 2011*. China Internet of Things R&D Center.

Coe, N., M., Kelly, P., F., Yeung, H., W., C., 2007. *Economic Geography: a contemporary introduction*. Blackwell Publishing.

Chui, M., Loffler, M., Roberts, R., 2010. The Internet of Things. *The McKinsey Quarterly*, Vol 2010, Num 2, p.70.

Commission of the European Communities. 2009. Internet of Things: An action plan for Europe [online] Available at:< http://cordis.europa.eu/fp7/ict/enet/policy_en.html > [Accessed 20 March 2012].

Daniels, P., W., 2012. Service industries at a crossroads: some fragile assumptions and future challenges. *The Service Industrial Journal*. 32:4, pp619-639.

Davis, M., M., Heineke, J., N., 2003. *Managing services: Using technology to create value*. Boston, McGraw-Hill/Irwin.

Dicken, P., 2011. *Global Shift Mapping the Changing Contours of the World Economy.* 6th Edition. The Guilford Press.

Dodson, S., 2003. The internet of things. *Guardian*. [online] Available at:<http://www.guardian.co.uk/technology/2003/oct/09/shopping.newmedia > [Accessed 20 April 2012].

Ericsson. 2011. More than 50 billion connected devices. *Ericsson White Paper.* Feb 2011.

Gago, D., Rubalcaba, L., 2007. Innovation and ICT in service firms: towards a multi-dimensional approach for impact assessment. *Journal of Evolutionary Economics*, 17, 1, p. 25-44.

Gilder, G., 1993. Telecosm: "Metcalfe's law and legacy". *Forbes*, 09/1993, p.158

Graham, S., Marvin, S., 2001. *Splintering Urbanism: Networked Infrastructures, Technological mobilities and the Urban Condition*. London: Routledge.

Harvey, D., 1989. *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*. Wiley-Blackwell.

IBM. 2012. Leading through connections: insights from global CEO study 2012.

Kellerman, A., 2000. Where does it happen? The location of the production and con-sumption of Web information. *Journal of Urban Technology* 7:45-61.

Kellerman, A., 2002. *The Internet on Earth A geography of information*. Wiley.

Kranenburg, R, et al., 2011. The Internet of Things. Paper for the 1st Belin Symposium on Internet and Society October 25-27.

Kurzweil, R., 2005. *The Singularity Is Near: When Humans Transcend Biology.* Penguin.

Li, F., Whalley, J., Williams, H., 2001. Between physical and electronic space: The implications for organizations in the networked economy. *Environment and Planning A*, 33:699-716

MIIT (Ministry of Industry and Information Technology of P.R.China). 2011. Develo-pment Program of Internet of Things in the Twelfth Five Year Plan Period (2011-2015).

Mackinnon, D., Cumbers, A., 1997. *An introduction to Economic Geography Globalization, Uneven Development and Place*. Pearson Education.

MIIT (China Academy of Telecommunication Research). 2011. *China Internet of Things White Paper* (in Chinese).

Miles, I., 1993. Services in the new industrial economy. *Futures*. Vol. 25 No.6 p.653-672

Miles, I., 2006). Innovation in services. In: *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Moss, M., L., Townsend, A., M., 2000. The Internet backbone and the American metropolis. *The Information Society*. 16:35-47.

O'Brien, G., 1992. *Global Financial Integration: The End of Geography*. Council on Foreign Relations Press.

Ogle, R., 2007. *SMART WORLD breakthrough creativity and the new science of ideas.* Harvard business school press.

Plumb, I., Zamfir, A., 2009. Managing Service Quality within the Knowledge-Based Economy:

Opportunities and Challenges. *Amfiteatru Economic*. Vol: XI, No. 26, p373-382.

Sheehan, J., 2006. Understanding service sector innovation. *Commun. ACM*, 49, 42-47.

Reed, D., 2001. The Law of the Pack. *Harvard Business Review*, February 2001, p 23–24

Roberts, J., 2000. The drive to codify: implications for the knowledge-based economy. Paper prepared for the 8th International Joseph A. Schumpeter Society Conference 28thJune -1st July 2000, University of Manchester, UK.

Santucci, G., 2010. The Internet of Things: Between the Revolution of the Internet and the Metamorphosis of Objects. *Forum American Bar Association* (2010). p1-23.

Shapiro, C., Varian, H., R., 1998. Information Rules: A Strategic Guide to the Network Economy. *Harvard Business Press*. p184

Technology Review. 2003. 10 Emerging Technologies That Will Change the World. *Technology Review*, Feb 2003, p33-49.

Tongia, R., Wilson, E., J., III. 2007. Turning Metcalfe on his Head: The Multiple Costs of Network Exclusion. Department of Engineering and Public Policy. Paper 120.

Valhouli, C., A., 2010. The Internet of things: Networked objects and smart devices. The Hammersmith Group.

Walter, C., 2005. Kryder's law. *Scientific American*, 08/2005, Volym 293, Nummer 2, p32.

II

5

The Transformative Roles of Knowledge-Intensive Business Services in Developing Green ICT: Evidence from Gothenburg, Sweden

Xiangxuan Xu and Patrik Ström

5.1 Introduction

The spatial complexities of green economy are sparse in the literature but there is growing interest in research on Environmental Economic Geography as an emerging field (Bridge 2008; Soyez and Schulz 2008), the local aspects of developing green technology (Weiss 2008), and the eco-network (Störmer 2008) as well as theoretical/empirical contributions to the conceptualization of green economy (Caprotti and Bailey 2014; Gibbs and O'Neill 2014). Ecological modernization and transition management approaches have been influencing geographers (Aoyama et al. 2010, p. 221; Cooke 2013). The ecological modernization perspective embraces the role of technology innovation and institution to unfold the green future. The transition theory applies a systematic perspective to stress that this process involves the co-evolution of social, economic,

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political and scientific-technological subsystems (Cooke 2011). However, none of these thoughts emphasizes the role of service activities, in particular the knowledge-intensive business services (KIBS) activities during green transition. If technology, institution and structure are the visible components of the 'greening' system, what are the soft conjunctions to connect and synchronize these heterogeneous activities? This question leads us to think about the roles of KIBS in the greening process of the economy. Previous research shows that KIBS are of importance in economic structural change and regional competitiveness as co-producers of innovation (Wood 2009; Bryson 2009; Ström and Wahlqvist 2010; Daniels 2013; Yeh and Yang 2013). A recent study of the business service industry for the European Union also shows the importance and potential of advanced services for future economic growth (EU 2014). One of the most significant contributions from these services is the intermediary role they play for knowledge transfer and productivity gains across industrial bases. Additionally, the international reach of these service providers is also important for achieving cross-sector competitive advantage. The techno-social transition to an energy-efficient, low-carbon economy is also a process of innovation. KIBS make up the 'glue' that holds heterogeneous economic activities together (Riddle 1986, p. 26) and act as facilitators, carriers or sources of innovation (Hertog 2000).

This chapter explores the roles of KIBS in developing green information and communication technologies (Green ICT) by using as examples cases from Gothenburg, Sweden. Green ICT has attracted increasing attention from academia, industry and policy makers as a promising response to environmental challenges. Although the ICT industry is responsible for 2 % of global carbon emissions,[1] an increasingly connected and digitalized world provides new ground for resource-efficient ICTs to enhance energy efficiency and reduce carbon footprint for sectors such as transport, building and energy (European Commission 2009; ITU 2008; OECD 2009a, b). Green ICT is a big family with various applications. In this chapter, we focus on one of its emerging movements—the green Internet of Things (G-IoT). The reason for this choice is that it is a dated case of green ICT applications that well captures the dynamics when green ICT emerges. A recent definition of G-IoT is proposed by Vermesan and Friess (2011, pp. 21–22): IoT technologies will allow greening of ICT through products and applications that converge with other industries and sectors to reduce infrastructure CO_2. G-IoT provides the technology and solutions that make full use of communications networks and Internet technologies to build future-oriented green intelligent cities, which provide a wide variety of interactive and control methods for the system of urban information and further support for building comprehensive systems for the development of urban ecology. G-IoT drives resource-efficient solutions such as smart grid, connected cars, smart manufacturers and so on.

However, the path from resource-efficient ICT technologies to green implementations is often non-linear and there is still much that we do not know about this process. The process of going green involves a range of business service expertise at each stage; KIBS offer specialized professional, business or technical expertise to other organizations (Wood 2009, p. 37). This chapter argues that KIBS take transformative roles by applying a service-informed approach (Wood 2005). It is not to say that the role of KIBS is more important than technologies, institutions or other driving forces, but rather that their role in this context is under-developed.

Section 5.2 defines KIBS in the green ICT context and builds the theoretical framework from literatures in KIBS roles in innovation, the ecological modernization/transition management perspective and the service-informed approach. Section 5.3 introduces the research design and explains the rationale of case selections. Based on the empirical data, Sect. 5.4 discusses the roles of KIBS in developing green ICTs. The chapter ends with a summary and discussion of implications for service research.

5.2 Theoretical Framework

5.2.1 Define KIBS in the Green ICT Context

Muller and Doloreux (2009) define KIBS as service firms that are characterized by high knowledge intensity and services to other firms and organizations, services that are predominantly non-routine. KIBS are highly associated with the creation and dissemination of knowledge, which are essential for society to move to a knowledge economy. Due to their heterogeneous nature, the definition and classifications of KIBS are varied according to different purposes. According to Revision 1.1 of the Nomenclature of Economic Activities, there are three categories of KIBS: 1) computer and related activities (72); 2) research and development (R&D) (73) and 3) legal, technical and advertising (74.1–4). Wei et al. (2007) reviewed more than 14 different kinds of classifications and summed up 21 sub-categories, among which the most recognized groups are R&D services; computer and information services; legal, management and technical consultancies; marketing; and advertising.

In the green ICT context, KIBS refer to activities that enable, foster and facilitate greener processes via computerization and digitalization. In this chapter, we define those activities in three groups: 1) R&D (hardware, software or solutions), 2) consultancy (legal, business and technical consultancy or market research/public opinion studies), and 3) other business services (exhibition; seminars, publications and conferences; newspaper, books or websites; training and education, funding (venture capital or other) and business match-making).

5.2.2 The Missing Piece from Ecological Modernization and Transition Management Approaches

The ecological modernization (EM) perspective provides a way to structure the dialects between social and ecological change (Harvey 1996, p. 377). According to Hajer (1995, p. 32), it is a modernist and technocratic approach that suggests a techno-institutional fix to the environmental problem. However, the EM approach is often critiqued on its technological optimism (Hannigan 1995, p. 116). Opponents argue that technology advancement does not by itself lead to environmentally beneficial effects and the availability of green technology does not by itself achieve mass adoption in the market. For instance, hydrogen-powered vehicles and fuel cells have not been successfully adopted because it requires massive modification of the entire system of electricity generation. The transition management (TM) approach provides a 'meta-coordination model' through which the social-technical regime is steered towards environmental governance (Geels 2005, p. 17). The TM approach shares the EM's general belief in a gradual transition towards sustainability, but they diverge on how the process is portrayed. The TM approach, unlike the EM approach, does not emphasize any single force (be it technology, institution or structure). Instead, it is based on the assumption that transition is a multilevel process involving the co-evolution of various actors (Kemp and Rotmans 2004; Kemp et al. 2007). For instance, the Dutch waste-management transition (Loorbach et al. 2003) is a transition process of co-evolution of the waste management subsystem and societal values and beliefs. The emphasis on 'co-evolution' means different subsystems are shaping but not determining each other (Kemp et al. 2007).

The EM approach fails to explain how a green technology reaches market adoption while the TM approach fills in this gap by saying that the transition is not only about green technologies, nor solely about institutional forces, but a systematic techno-social transition that involves the co-evolution of various related actors interacting at multiple levels. However, the TM approach has not yet developed sufficient explanations for the factors that hold heterogeneous interests of different actors together to facilitate the co-evolutionary path (Shove and Walker 2007). Therefore, the missing piece from the EM and TM approaches is identified as the factors that facilitate heterogeneous actors co-evolving together for the green vision.

5.2.3 Relationships, Interactivities and the Intangibles: Bring KIBS into the Scene

To further develop insights on the factors that facilitate heterogeneous interests from various actors on the co-evolutionary path, we look at the roles of KIBS during this innovation process. KIBS naturally play a role in developing green ICT as most of the actors involved in developing green ICT applications are themselves categorized as KIBS. More importantly, recent research shows KIBS as actors of knowledge transformation (Muller and Zenker 2001). Hertog (2000) argues that KIBS function as facilitators, carriers or sources of innovation, and some KIBS function as co-producers of innovation because of their almost symbiotic relationship with client firms. Researchers have pointed out the importance of relationships and interactivities in KIBS networks with other actors during the innovation process, specifically the importance of what are known as the 'intangibles'. As Hertog (2000, p. 491) put it, 'in addition to discrete and tangible forms of knowledge exchange, process-oriented and intangible forms of knowledge flows are crucial in such relationships'. Other than technologies, the importance of the 'intangibles' in relationships and interactivities sheds light on our inquiry into the factors that facilitate heterogeneous actors on the greening co-evolutionary path. In Wood's (2005) service-informed approach, he further categorized those factors into three aspects and extended the intangibles in knowledge flow to knowledge, learning and trust.

Wood (2005) claimed that competitiveness has been more driven by "knowledge-intensive service functions" in the complex private and public sectors nexus rather than where the technologies are invented. He (2005, p. 432) proposed to view innovation as a service-based process because successful technological innovation involves a great amount of specialized service expertise as well as the processes and relationships that characterize it, which include: 1) the interactivity between sectors and firms; 2) orientation to market outcomes; and 3) the importance of intangibles (e.g., knowledge, learning and trust). The service-informed approach emphasizes KIBS functions at the nexus of complex private and public sectors and interactivities among sectors and firms, which is helpful for explaining how the heterogeneous actors interact at multiple levels. The point of orientation to market outcomes helps to explain the market needs for green ICT. The importance of the intangibles such as trust and learning helps to explain the factors that bring different activities and competences together to implement green ICT applications. Therefore we argue that the service-informed approach is the missing piece from the TM and EM approaches.

5.2.4 Towards a Synergy: The Roles of KIBS in Developing Green ICT

Three aspects are proposed in the service-informed approach to characterize the service expertise, process and relations that are involved in developing a successful technology innovation. We therefore frame the roles of KIBS in developing green ICT by using the ACT (ADHESIVE, CANAL and TELESCOPE) Framework. ADHESIVE is named for the importance of intangibles (such as knowledge, learning and trust), which includes cohesive forces to facilitate heterogeneous economic activities such as providing meeting places, building trust and coordinating func-tions and regulation. CANAL refers to the knowledge/technology inter-activities between sectors and fi rms. TELESCOPE is the orientation to market outcomes, which refers to the knowledge creation towards the greening vision via digitalization. KIBS activities are divided accordingly into these three roles. Reputation in expertise is not a tangible KIBS activ-ity although this asset provides a general trust for other actors within or outside the fi rm's network. Due to its importance to the ADHESIVE function, we categorize reputation as an intangible KIBS activity under this category. Other business services such as exhibition; seminars, pub-lications and conferences; newspaper, books or websites; training and education, funding (venture capital or other) and business match-mak-ing exercise both the roles of CANAL and ADHESIVE because these activities are often enacted across sectors and fi rms and involve learning or trust building. Activities in consultancy (legal, business and technical consultancy) and technology transfer services are examples of CANAL aspects because they also occur across sectors and fi rms. R&D, mar-ket research/public opinion studies and business incubators focus on new knowledge and technology creation therefore they belong to the TELESCOPE category (see a summary in Table 5.1).

5.3 Case Selection and Method

5.3.1 Technology: IoT and G-IoT

Generations of innovation from a divergent cluster of ICTs generate billions of networked objects with embedded intelligence. Th-ese net-worked objects together with human beings and social networks, are transforming the world into an information and knowledge system (ITU 2005; European Commission 2009; MIIT 2011). By the year 2012, more than 8.7 billion devices were connected to the internet and the number will reach 50 billion in 2020 (Evans 2012; Ericsson 2012; European Commission 2012).

Table 5.1 The ACT framework: the roles of KIBS in developing green ICT

Roles	Explanation	KIBS activities
ADHESIVE the importance of intangibles	Cohesive forces to facilitate heterogeneous activities together such as providing a meeting place, building trust and coordinating functions	Other business services (exhibitions, seminars, publications, books, websites, conferences, technology transfer services, training and education, funding (venture capital or other) and business match-making, business incubator); Reputation in expertise
CANAL the interactivity between sectors and firms	Knowledge/technology interactivities between sectors and firms	Consultancy (legal, business and technical consultancy) and technology transfer services; Other business services (exhibitions, seminars, publications, books, websites, conferences, training and education, funding (venture capital or other) and business match-making, business incubator)
TELESCOPE orientation to market outcomes	Knowledge creation to the greener process via digitalization	R&D, market research/public opinion studies and business incubators

Some are not only connected but also have sensing abilities, which means they are active contributors of information fl ow rather than merely passive containers. Some also can communicate and coordinate activities with each other without or with less human interventions. This emerging phenomenon is called the 'Internet of Things' (IoT). IoT, like many other general purpose technologies, has impacts across many industries and sectors. The global IoT major players are operators and system integrators providing ser-vices on a large scale (e.g., Google, IBM, Ericsson and GE) or leading platform developers at the boundary of manufacturing and services (e.g., Microsoft, SAP and Oracle). The value of IoT applications is mainly in providing useful information and services (Xu 2012). Due to the heterogeneous, networked and context-based characteristics, IoT provides a unique lens for better understanding service research on two contemporary challenges: 1) the transformation of conceptualizing service as co-production between a client and a service provider to the multi-actor frameworks of a plurality of providers, suppliers and varied actors interacting with each other (Bryson et al. 2012, p. 651); and 2) the transformation of the global economy from goods-oriented to service solution-oriented (Chesbrough and Spohrer 2006; Spohrer and Maglio 2008); the value shifts from the tangibles to the combination of the tangibles and the intangibles.

The 'green' gene imbedded in IoT applications (G-IoT) is characterized by automation, telematics and quantifying human-environment interactions (Xu 2012). Automation/telematics enable process optimizing through real-time communication; as a result providing services to improve efficiency. For example, connected vehicles will be able to tell the driver if there is a traffic jam or accident ahead and suggest an alternative route in advance. Automation and telematics also increase the flexibility of organizing activities by reducing the restrictions on time and places. If more jobs can be done from a distance, it will reduce the energy consumption on human transportation. Quantifying human-environment interactions is enabled by connecting the physical world with sensors. By getting the useful information from the change of environment, people can better adjust their activities to reach a more sustainable way of living.

5.3.2 Gothenburg Region and the Cases

Situated on the west coast of Sweden, the Gothenburg region has a well-known track record for sustainable growth, transforming from an industrial tradition to a knowledge-intensive economy. It is ranked as the 16th leading region in knowledge competitiveness[2] worldwide and tops in Europe in R&D expenditure per capita by business.[3] In 2011, the ICT industry was the 3rd largest employer of the region (9.6 %) after the logistics transportation (12.9 %) and automotive industries (20.6 %).[4] The region's ICT expertise has emerged from the competences accumulated from radar, sensor technologies and high velocity and is considered the number-one location for telematics in the world.[5] The biggest ICT companies in the region are Ericsson, Volvo IT, and TeliaSonera (each with more than 1,000 employees), while Volvo Cars is the biggest employer in the region overall.

We present the following six projects collected from the region in 2013.

1. Commute Greener

   Description: Commute Greener is a mobile application for measuring the time, efficiency and environmental impact of daily commuting. It helps to record CO_2 footprints on commuting via location-based services. The application allows users to join an online community, and by aggregating the shared routines and public transportation information, it is able to suggest to users greener ways of commuting such as taking buses and trams or car sharing. It is designed using a ramification method, which provides users with a sense that they are playing a 'game' to encourage them to change their commuting styles. Users get rewards for achieving goals (e.g., virtual badges to share on Facebook, coupons for free coffee). It has a free version for users and tailor-made versions for VIP clients like the Word Wildlife Federation.

   Main partners: The application was invented and developed by Volvo IT. The location-based technical service platform provider is Pocketweb. VIP clients are co-producers of each tailor-made version.

   Geography: Mexico City, India, Sweden, San Francisco

   Development phase: Incubating

   Application area: Sustainable commuting
2. Free-Floating Car Sharing

   Description: Free-floating car sharing is a new type of location-based car-sharing service. Conventionally, rental car services require users to pick up and return cars at fixed locations. This new service provides one-way rentals without this requirement. Users can return cars anywhere in the service areas. The pilot was launched in the Jiading District of Shanghai, China.

   Main partners: Viktoria Swedish ICT in Gothenburg is responsible for concept development and the feasibility study. Shanghai International Automobile City is the client. One company each in Sweden and China are technology providers. An electric car manufacturer in Jiading is the co-developer. Funding agencies are VINNOVA (the Swedish innovation agency) and MOST (China's Ministry of Science and Technology)

Geography: The Jiading District of Shanghai, China

Development phase: Concept development

Application area: Sustainable mobility

3. Megacity Smart Transportation Services

Description: This project, which we've kept anonymous at the request of the key manager, makes public transportation data available to all travellers. It develops easy-to-use mobile services with the purpose of reducing environmental impact in megacities by encouraging the use of high-capacity public transportation. The project is for a megacity in a developing country with a population of more than 10 million.

Main partners: One R&D institute from Gothenburg is responsible for concept development and project plan. The project is partnered with a technology consulting company and supported by the municipal science and technology department in the megacity.

Geography: A city in a developing country with a population of more than 10 million

Development phase: Concept development

Application area: Sustainable transport

4. Connected Filter in the Cloud

Description: This project connects all the filters in a factory used by the paper industry by using Cloud computing to increase the efficiency of reducing air pollution during the manufacturing process.

Main partners: Semcon AB (a global company active in the areas of engineering services and product information) and a client from the paper industry (the client's name is kept anonymous as required by Semcon AB) are partners in this project.

Geography: Sweden

Development phase: Implemented

Application area: Smart manufacture

5. HeERO

Description: This project develops a pan-European interoperable and harmonized in-vehicle emergency call system, which aims to make it possible for any vehicle from any European country travelling across Europe to use the 'e-Call' system when there is a crash. Calls can be made manually, but in case passengers are not able to operate the car will automatically call the nearest emergency centre.

Main partners: The Swedish team is comprised of Security Arena Lindholmen (an expert organization); Actia Nordic AB (a manufacturer of electrical and electronic equipment for motor vehicles); Swedish Transport Administration (a public authority); Ericsson (a telecommunication products provider); and Volvo Cars (an OEM).

Geography: Nine European countries make up the HeERO 1 consortium. They are Croatia, Czech Republic, Finland, Germany, Greece, Italy, The Netherlands, Romania and Sweden. The aim of the project is to eventually offer the service in all EU member states.

Development phase: About to implement

Application area: Safety

6. Connected Vehicle Cloud (CVC)

   Description: Ericsson's Connected Vehicle Cloud (CVC) is based on the company's multiservice delivery platform (Ericsson Service Enablement Platform) and is being used to create new communication channels for drivers, passengers and connected cars as well as support new business models and revenue streams.

   Main partners: Ericsson is partnered with various automotive manufacturers as well as developers and drivers.

   Geography: Global; so far the platform has been used by more than 100 service providers in five continents.

   Development phase: Implemented

   Application area: Horizontal telecom service platform

5.3.3 Method and Limitations

This chapter uses close dialogues with G-IoT project executives as the method for conducting the research. Close dialogue is a proven method for industry analysis in the study of economic geography, especially for geographers to understand the economic diversity in relation to broader, higher-tier processes of economic change (Clark 1998). This method demands reflexivity of the interview data. That means it fits the research questions that are explorative.

As G-IoT projects often involve a set of actors across the boundaries of firms and sectors, the unit of analysis is project-based. First, we asked the key project managers of each project to tell us what kind of G-IoT-related KIBS activities they are performing at their organizations (where the key project manager works) according to our definition of KIBS activities in the green ICT context. Then, we asked them to describe the development, actors and relationships in a G-IoT case that they had led or were deeply involved with during the following three phases: initiation, development and evaluation/knowledge dissemination. Priority was given to deep knowledge of the entire project because the questions required managers to disclose the important partners and intermediary activities involved. Instead of directly asking managers about the roles of KIBS activities as defined in Table 5.1, we asked them for descriptions that provided rich data without requiring them to categorize the information into specific knowledge categories and frameworks. Due to time limitations, the managers were asked to focus on one project and each project was analysed as a case for the purposes of this chapter.

Six G-IoT cases were collected in total. As one can see from the descriptions provided earlier, the projects are varied in regards to development phase status, scope of geography and application area. This variety causes difficulties for theoretical generation. Due to the limited number of sample cases, rather than providing a full picture of the whole industry, this chapter aims to explore the emerging field of developing G-IoT applications and to give a perspective on interesting aspects during the process.

5.4 Empirical Discussions

5.4.1 Types of G-IoT-Related Activities Performed

We asked each key manager of the six cases to tell us the kinds of G-IoT-related KIBS activities performed at each of their organizations. Because two managers are within the same organization we ended up gathering data from a total of five organizations. R&D of applications and legal, business and technical consultancy were considered the most performed

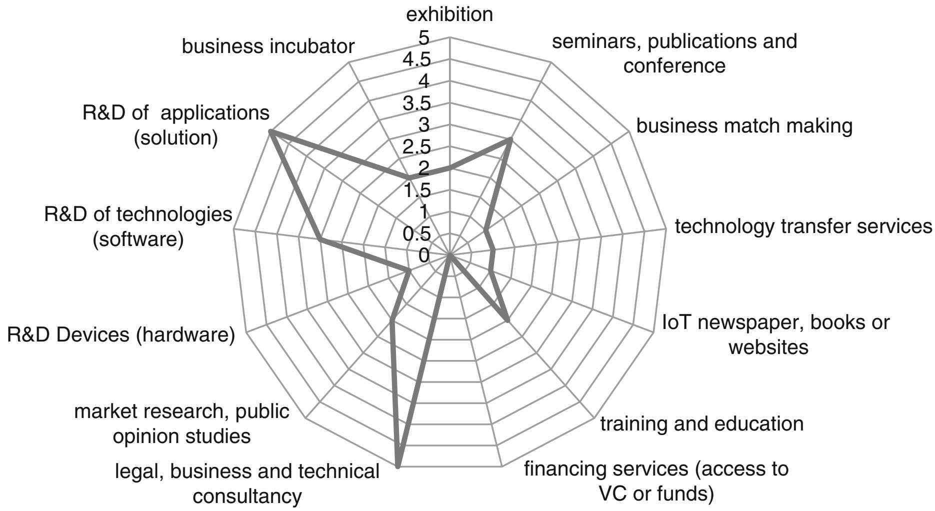

Fig. 5.1 KIBS activities that are performed at the organizations (data collected in 2013)

KIBS. This result is not surprising given the conventional view of the dominance of R&D and consultancy activities in KIBS. However, it is interesting that 'applications (solution)' was chosen as the most performed R&D activity (See Fig. 5.1).

The term 'application' was added during the first dialogue as a complementary choice. One of the managers considered it to be more accurate compared with hardware/software or products/services. This opinion was shared by other managers. They felt that differentiating between products and services didn't make sense because both are often highly integrated into a single application that offers certain solutions.

Managers from Volvo IT and Ericsson chose 'business incubator' as the most performed KIBS. This highlights the importance of organizational entrepreneurship in this time of ever faster technological changes and global competition. In fact, the Commute Greener project is currently in the incubating phase. According to the managing director at Commute Greener, Mr. Magnus Kuschel, the project was developed based on an idea from Volvo employees. In 2009, the company launched the prototype internally to help employees measure the environmental impact of their daily commuting and improve efficiency via an app on their mobile

Fig. 5.2 KIBS activities that are performed at the organizations by three roles

phones. The result was surprisingly successful and the employees reduced their CO_2 footprint by 30 % just in the first month. The city of Gothenburg heard about this and approached Volvo to help them develop a similar programme. This illustrates that the ability to grow new businesses and new organizations out of existing organizational structure is of great significance for today's technologically driven multinational enterprises.

Figure 5.2 summarizes the KIBS activities in Table 5.1 by way of the three roles defined in our ACT Framework. We can see that the roles of CANAL and TELESCOPE come out on top, which stresses the importance of interactivity and new creation of knowledge during the innovation process. However, it does not mean that the role of ADHESIVE is less important as we will discuss in the following section.

5.4.2 Roles of KIBS Activities in Developing Green ICT Applications

Each key manager interviewed chose a G-IoT project that they knew very well and described the case in three phases: the initiation phase, the development phase and the evaluation/knowledge dissemination phase. Afterwards, the authors analysed the details from their stories and put those heterogeneous activities into the three roles as defined in the ACT Framework. For example, in case 1 (Commute Greener) the project initiated in Gothenburg came about as a result of a successful internal prototype at Volvo. Therefore, this activity is marked with a T (TELESCOPE). Because the project was initiated overseas at Volvo India, it is marked with an A (ADHESIVE). Detailed marks for all six cases can be found in the Appendix and the final result is shown in Fig. 5.3

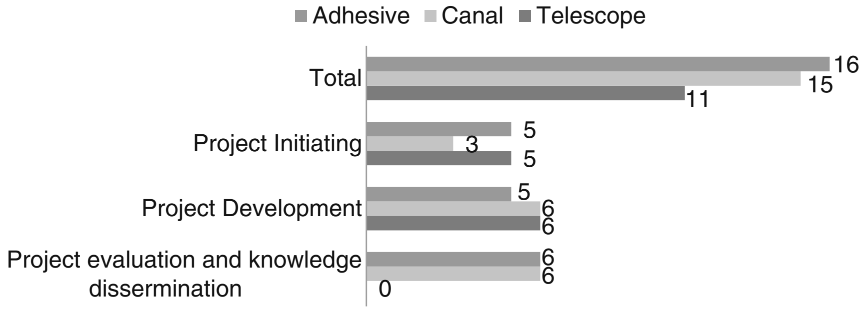

Fig. 5.3 Roles of KIBS in different project development phases

The ADHESIVE role had the highest marks in this second analysis, which contrasts the results during the first phase of our research. The reason for this could be that it is difficult to observe the ADHESIVE function as including activities concerning trust; networking and coordinating heterogeneous actors are tacit and intangible. However, during the dialogues with managers, the importance of the 'intangibles' was more than clear. In cases 1, 2, 3, 4 and 6, ADHESIVE function was also the enabler for initiating the projects. During the project development phase, all projects that involve multiple actors consider the 'intangibles' as important ingredients. Th is factor is especially important for cases developing in emerging markets or performed in multiple countries. Mr. Johan Wedlin, the project leader of case 2 (free-floating car sharing), and Mrs. Gunilla Rydberg, the project leader of case 5 (HeERO), both emphasized the difficulties and importance of building a consoli-dated consortium of different actors with complementary expertise and resources. Trust could be built through a broker (case 3), by an organiza-tion's presence in a foreign market within the global network (case 1), or by credit of previous success (case 6). Each case tends to have its own story, but face-to-face interaction still plays an essential role in building and maintain trust.

Following ADHESIVE, the role of CANAL is increasingly important after the initiation phase. It is understood that knowledge exchange and customer interactions increase over time. For instance, in case 1 the Commute Greener application is constantly updated based on the feedback from and interaction with various clients.

The role of TELESCOPE received 11 points and it is clear that this func-tion occurred mainly during the initiation and development phases. Technology innovation is an evolutionary process that sometimes depends on the right time, the right place and the right people. Th e project manager of case 3 said the starting point of the project was a convergence of the organization's interest, the appearance of the broker and the needs of the client. Nevertheless, those who are well prepared can catch the 'wind'.

5.5 Summary and Implications for Service Research

5.5.1 The Importance of the 'Intangibles'

In this chapter we developed the ACT (ADHESIVE, CANAL and TELESCOPE) Framework—based on the insights from the service-informed approach—to explore the roles of KIBS in developing green ICTs. The transformative roles that KIBS play in this context are due to the importance of the 'intangibles' in relationships and interactivities to bring actors with different resources and interests together. The results from analyzing six G-IoT cases from the Gothenburg region of Sweden show that all three roles matter in an interactive way. Without the role of TELESCOPE, there will be no green technology to bring to the market; without the role of ADHESIVE and CANAL, the technology might not be able to be implemented successfully by the right people in the right place and at the right time. Our cases show that the ADHESIVE role is crucial though rather tacit and difficult to quantify. Reputation in expertise is an intangible asset while it brings trust that is essential for collaborations among different actors. Because face-to-face communication is essential, the role of ADHESIVE often works together with the role of CANAL. During the non-linear path of developing green ICTs, the 'intangibles' (such as trust, cross-boundary tacit knowledge sharing and the willingness to seek new opportunities even among competitors) embedded in the interactivities of business social relationships play a crucial role.

The other aspect to the importance of 'intangibles' is reflected in how value is created for the G-IoT applications. They are often a combination of software, hardware, platform and services as a whole, but the value doesn't come from those tangible devices of wires, sensors, screens and chips. It relies on how many users or other devices are connected to it and their interactions with others (e.g., Commute Greener doesn't own any cars and the service of car-sharing is based on the users' interactivity and engagement).

5.5.2 Region as a Test Bed for Green Technology/Services

The need for 'face-to-face' communication for purposes of building trust and encouraging tacit knowledge exchange, as revealed in our empirical analysis provides a rationale for seeking out the Gothenburg region as a test bed for green technologies/services. It does not mean that co-location must lead to trust and tacit knowledge exchange, but co-location enables face-to-face communication. KIBS are usually co-located within multinational corporations. Leading multinational corporations are vital for the direction of green innovation because they often have the resources and capability to lead innovation projects. Among these six cases from Gothenburg, we found a dominating green application area: green transport/vehicles. Two companies' showed up frequently in our research—Ericsson and Volvo, both of which are powerful engines of innovation and competence accumulation in this region. This is a case where a certain area's competence may pave the way to transform to another competence. In Gothenburg, the competence accumulated in telecom and transportation laid the foundations for developing green transportation and connected vehicles. This ability and opportunity to grow new competence based on existing ones is an important step towards regional development, and the nexus of KIBS hold the transformative power. This power is related to the important role of KIBS as intermediaries between sectors to facilitate dynamic knowledge transfer that can prevent lock-in effects or negative path dependency. Knowledge transfer between sectors is key for the growth of the green economy. In this case, the Gothenburg region of Sweden can be understood as a test bed for green technologies and service in green transport/vehicles.

5.5.3 The Transformation of Service to the Multi-Actor Frameworks Interacting with Each Other

This transformation is identified by Bryson et al. (2012) as one of the challenges in future service research. In this chapter, this challenge can be understood in three aspects. Firstly, the **technology/service** itself is in a multi-framework. Most of the G-IoT applications are multi-actors in nature as the value of their services are based on users' connectivity and interactivity. The Ericsson Connected Vehicle Cloud can be connected to countless users, cars or business partners globally. Secondly, the **business relationship** is multi-framework. In our empirical discussions, all G-IoT cases, excluding case 4 (a typical one client-one technology consultancy provider), are indeed a network of plurality of providers, suppliers and varied actors. They can be the users, the regulators and the business partners within or outside of firms' existing business networks. These interactions can also cross the boundaries of industry and sector. Thirdly, we address **geography**. The knowledge of innovation is in a state of constant upgrade and change from both inside and outside the region. KIBS are in this respect at the core of activities taking place on a multi-level geographical scale where local presence and international reach through contacts and clients are essential for knowledge transfer. Knowledge and policy networks are complex and take time to develop. This creates regional competitive advantage that can be sustained over time and makes it more difficult for actors to leave for other locations. Therefore, the interactive multi-actor framework of service conceptualization in our cases includes three levels of analysis—technology/service, business relationship and geography.

Appendix

A summary of the roles of KIBS activities in three phases of developing G-Io projects.

Project	Project Initiation	Project Development	Project evaluation and knowledge dissemination
1. Commute Greener	**In Gothenburg Sweden**: City of Gothenburg came to VOLVO IT after hearing the successful story of the internal prototype **In Mexico City**: got contact during a conference **In San Francisco**: due to the new regulation of reporting CO_2 footprint **In India:** through VOLVO Group in India (A, C, T)	**Technology platform**: Pocket web's Pocket Life Platform which provides location based services across web and mobile operating systems. **Client**: There are two versions of the applications. The free version is open and free to all people and the tailor-made version for clients who ask for customization functions. Through the interactions with clients, both the public and customized applications get improved. (A,C,T)	Conference, internal or external seminars; project evaluation report and case studies; website and blog; media report (A,C)

2. Free-floating Car Sharing	Project initiated during the visit of Shanghai International Automobile City Group to Viktoria Institute. However the institute accumulated knowledge by previous projects in e-mobility for instance Vattern fall asked to see what the barriers of electric cars in Sweden are. (A,C,T)	For a cross-country cooperation project, it is important to **consolidate the partnership** among all the actors involved in the project between the R&D, technical support, electric car manufacturer, legal regulation and test site local support. (T,C,A)	Conference, internal or external seminars; project evaluation report and case studies; website; media report (A,C)
3. Megacity smart transportation services*	Project initiated by a broker who knew the client's needs and the organization's ability. (A,C)	The same as the previous case, this project involves multi-stakeholders in both private and public domains from different countries, therefore to get full support from the local authority and cooperation among actors are important.(T,C,A)	Project evaluation report; probably Conference, internal or external seminars or publish the case study (A,C)
4. Connected filter in the cloud	Client came to Semcon with the task (A)	This is a typical client-technical consultancy case therefore the interactions with client and Semcon's expertise are important factors(T,C)	Project evaluation report and case studies; internal seminars(A,C)

(*continued*)

Appendix (continued)

Project	Project Initiation	Project Development	Project evaluation and knowledge dissemination
5. HeERO	EU Commission policy imposed (T)	During the first pilot phase, 9 member states have been worked together to develop operational and functional requirements needed to upgrade all eCall related service and implement standard. The challenge is to provide harmonized e-call services across the whole Europe given by the many differences among member states (A,C,T)	Conference, internal or external seminars; project evaluation report and case studies; website; media report(A,C)
6. Connected vehicle cloud	Based on the multiservice delivery platform in Ericsson service enablement and M2M service enablement capabilities to provide horizontal technical platform for connected car services (A,T)	Interactions with drivers, passengers, automotive manufacturers, business partners. As it is also an open platform to produce apps, such interactions also involves developers. (A,C,T)	Conference, internal or external seminars; project evaluation report and case studies; website and blog; media report; world competition (first place in Enterprise Solution at

References

Aoyama, Y., J.T. Murphy, and S. Hanson. 2010. *Key concepts in economic geography*. Thousand Oaks, CA: SAGE Publications.

Bridge, G. 2008. Environmental economic geography: A sympathetic critique. *Geoforum* 39: 76–81.

Bryson, J.R. 2009. Business services. In *International encyclopedia of human geography*, ed. K. Rob and T. Nigel, 368–374. Oxford: Elsevier.

Bryson, J., L. Rubalcaba, and P. Ström. 2012. Services, innovation, employment and organization: Research gaps and challenges for the next decade. *The Service Industrial Journal* 32(4): 641–655.

Caprotti, F., and I. Bailey. 2014. Making sense of the green economy. *Geografiska Annaler, Series B, Human Geography* 96(3): 195–200.

Chesbrough, H., and J. Spohrer. 2006. A research manifesto for services science. *Communications of the ACM* 49(7): 35–40.

Clark, G.L. 1998. Stylized facts and close dialogue: Methodology in economic geography. *Annals of the Association of American Geographers* 88: 73–87.

Cooke, P. 2011. Green innovation. In *Handbook of regional innovation and growth*, ed. P. Cooke, B.T. Asheim, and R. Boschma, 434–446. Cheltenham: Edward Elgar Publishing.

———. 2013. Transition regions: Green innovation and economic development. In *Cooperation, clusters, and knowledge transfer*, ed. J.J.M. Ferreira, M. Raposo, R. Rutten, and A. Varga, 105–125. Berlin: Springer.

Daniels, P.W. 2013. The transition to producer services in China Opportunities and obstacles. In *Producer services in china economic and urban development*, ed. A.G. Yeh and F.F. Yang, 29–51. London: Routledge.

ERICSSON. 2012. *More than 50 billion connected devices – Taking connected devices to mass market and profitability*. Ericsson white paper. www.ericsson.com/res/docs/whitepapers/wp-50-billions.pdf.

European Commission. 2009. *Mobilising Information and Communication Technologies to facilitate the transition to an energy-efficient, low-carbon economy. Communication-COM*, 111. Brussels: European Commission.

———. 2012. *Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. The Digital Agenda for Europe - Driving European growth digitally*. Brussels: European Commission.

EU. 2014. *High level group on business services. Final report, April 2014*. Brussels: EU.http://ec.europa.eu/enterprise/policies/industrial-competitiveness/industrial-policy/hlg-business-services/index_en.htm.

Evans, D. 2012. *The internet of everything: How more relevant and valuable connections will change the world*. San Jose, CA: CISCO Internet Business Solutions Group (IBSG). www.cisco.com/web/about/ac79/innov/IoE.html.

Geels, F.W. 2005. *Technological transitions and system innovations: A co-evolutionary and socio-technical analysis*. Cheltenham: Edward Elgar Publishing.

Gibbs, D., and K. O'Neill. 2014. The green economy, sustainability transitions and transition regions: A case study of Boston. *Geografiska Annaler, Series B, Human Geography* 96(3): 201–216.

Hajer, M.A. 1995. *The politics of environmental discourse: Ecological modernization and the policy process*. Oxford: Clarendon.

Hannigan, J.A. 1995. *Environmental sociology: A social constructionist perspective*. London: Routledge.

Harvey, D. 1996. *Justice, nature and the geography of difference*. New York: Wiley.

Hertog, P.D. 2000. Knowledge-intensive business services as co-producers of innovation. *International Journal of Innovation Management* 4(04): 491–528.

ITU. 2005. *The internet of things*. Geneva: ITU.

———. 2008. *ICTs or e-environment. Guidelines for developing countries, with a focus on climate change*. Geneva: ITU. www.itu.int/ITU-D/cyb/app/docs/itu-icts-for-e-environment.pdf.

Kemp, R., D. Loorbach, and J. Rotmans. 2007. Transition management as a model for managing processes of co-evolution towards sustainable development. *The International Journal of Sustainable Development & World Ecology* 14: 78–91.

Kemp, R., and J. Rotmans. 2004. *Managing the transition to sustainable mobility. System innovation and the transition to sustainability: Theory, evidence and policy*, 137–167. Cheltenham: Edward Elgar Publishing.

Loorbach, D., S. Parto, and R. Kemp. 2003. From waste disposal to waste management: Transitions in waste management in the Netherlands. Paper presented at the Netherlands Organization for Scientific Research (NWO).

MIIT (Ministry of Industry and Information Technology of P.R. China). 2011. *Development Program of Internet of Things in the 12th Five Year Plan Period (2011-2015)*. Chinese version is accessed online by 2012-06-25 at www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/14457071.html.

Muller, E., and D. Doloreux. 2009. What we should know about knowledge-intensive business services. *Technology in Society* 31: 64–72.

Muller, E., and A. Zenker. 2001. Business services as actors of knowledge transformation: The role of KIBS in regional and national innovation systems. *Research Policy* 30(9): 1501–1516.

OECD. 2009a. *Smart sensor networks: Technologies and applications for green growth*. Paris: OECD. www.oecd.org/internet/interneteconomy.

———. 2009b. *Green growth: Overcoming the crisis and beyond*. Paris: OECD.

Riddle, D.I. 1986. *Service-led growth: The role of the service sector in world development*. New York: Praeger.

Shove, E., and G. Walker. 2007. CAUTION! Transitions ahead: Politics, practice, and sustainable transition management. *Environment and Planning A* 39: 763–770.

Soyez, D., and C. Schulz. 2008. Facets of an emerging Environmental Economic Geography (EEG). *Geoforum* 39: 17–19.

Spohrer, J., and P.P. Maglio. 2008. The emergence of service science: Toward systematic service innovations to accelerate co-creation of value. *Production and Operations Management* 17: 238–246.

Störmer, E. 2008. Greening as strategic development in industrial change – Why companies participate in eco-networks. *Geoforum* 39: 32–47.

Ström, P., and E. Wahlqvist. 2010. Regional and firm competitiveness in the service-based economy: Combining economic geography and international business theory. *Tijdschriftvooreconomische en Socialegeografie* 101: 287–304.

The Swedish Central Business Register. 2011. The 100 Largest Employers in the Gothenburg Region, www.businessregiongoteborg.com/download/18.775106461353f5a20961b4b/1389235365475/The+100+Largest+Employers.pdf.

Vermesan, O., and P. Friess. 2011. *Internet of things-global technological and societal trends from smart environments and spaces to green ICT*. Aalborg: River Publishers.

Wei, J., Y. Tao, and L. Wang 2007. The Concept and Classification of Knowledge-Intensive Business Service. *China Soft Science* 1: 33–41. (魏江, 陶颜, 王琳. 知识密集型服务业的概念与分类研究[J]. 中国软科学, 2007 (1): 33–41.).

Weiss, G. 2008. The influence of the local level on innovations in environmental technology: The case of the German kraft pulp industry. *Geoforum* 39: 20–31.

Wood, P. 2005. A service-informed approach to regional innovation – or adaptation? *Service Industries Journal* 25(4): 429–445.

———. 2009. Knowledge intensive business services. In *International encyclopedia of human geography*, ed. K. Rob and T. Nigel, 37–44. Oxford: Elsevier.
Xu, X. 2012. Internet of things in service innovation. *The AMFITEATRU ECONOMIC journal* 14: 698–719.
Yeh, A.G., and F.F. Yang. 2013. Producer services and China's economic and urban development. In *Producer services in China economic and urban development*, ed. A.G. Yeh and F.F. Yang, 3–25. London: Routledge.

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The Contextual Dynamics of Internet of Things Applications in Smart Public Bike Sharing Services

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The past decade has witnessed the emergence of Internet of Things (IoT) technologies in public service innovation. As the technical characteristics of IoT technologies are rather identical around the globe, one might wonder whether the location still matters for their adoptions. Smart public bike sharing (PBS) scheme is one of the world's most widespread public IoT applications. Prior studies of smart PBS schemes find the positive effects on the host city's image and sustainable mobility. However, less attention has been paid to the impact of the host city's context on the evolution of their service characteristics. The paper proposes a model that explicitly includes the contextual dynamics of public service innovations that utilize IoT. Then the model is used to analyze two empirical cases from Sweden and China, respectively. The results reveal that public motives, user preferences, and governance can impact the evolution of the service characteristics of smart PBS schemes, which is important for smart PBS planners, operators, and policymakers to consider. The best PBS scheme is the one that adapts to the characters of the host city and the changing needs of the users. Moreover, the study reflects the new complexities that arise for digital public services, such as the protection of data and privacy.

Keywords: Public bike sharing (PBS); public service innovation; internet of things.

1. Introduction

A recent driving force of innovations in public transport service is the introduction of the Internet of Things (IoT) (Zhou *et al.*, 2012; Weber *et al.*, 2014; European Commission, 2015; Behrendt, 2016). IoT technologies provide opportunities to lower the marginal cost of public transport services, which was impossible or too costly to provide in the past (Whiteman, 2014). A familiar example is smart public bike sharing (PBS) scheme. Implemented in more than 800 cities, these services are probably the world's most vastly diffused applications of IoT (Fishman, 2016). As the enabling technologies, e.g. the network technologies and the internet, are pervasive across continents, one might wonder if place still matters for the adoption of global technology. This paper argues that place still matters and addresses the importance of the contextual dynamics that impact the implementation and evolution of smart PBS schemes in different locations.

The literature on smart PBS schemes has grown rapidly in the last 10 years (Fishman *et al.*, 2013; Fishman, 2016). Previous studies focus on how smart PBS schemes work

(Bonnette, 2007; DeMaio, 2009; OBIS, 2011; Fishman *et al.*, 2014, 2015; Yang *et al.*, 2015; Mátrai and Tóth, 2016). Another strand of researches examines the positive effects of the schemes on city image and sustainable mobility (Midgley, 2011; Mrkajić and Anguelovski, 2016; Segui Pons *et al.*, 2016; Behrendt, 2016). This body of literature has studied how the adoption of IoT technologies in smart PBS services impacts on the host city. The present paper looks at the other way around — how does the host city's context influence the evolution of the service characteristics of smart PBS schemes? The paper argues that contextual factors of the host city can impact the evolution of smart PBS service characteristics. It, therefore, contributes to the study of smart PBS schemes by viewing it as a dynamic innovation process that is influenced by various technical and non-technical factors.

The first aim of the paper is to develop a model that explicitly includes the contextual factors to analyze the innovation process of public services that utilize IoT. The model is built by combining theories from the characteristics-based approach in service innovation literature (Lancaster, 1966; Saviotti and Metcalfe, 1984; Gallouj and Weinstein, 1997) and the geography of information technologies (Kellerman, 2002; Wilson *et al.*, 2013). Service innovation theory shows that factors such as the competences of the service providers and users, the technical and non-technical characteristics (such as branding and organization), influence the service characteristics during the innovation processes. The geography of information technologies stresses that even though the technologies are pervasive, the production and consumption of them are place-dependent. Local conditions such as government policies and specific customs can all influence the deployment and development of information technologies in a certain place. An integration of the two explains why geography matters when globally identical technologies are adopted at different locations. Therefore, the proposed model has two major contributions. First, the emphasis on the local contexts accentuates a human-centered approach to the adoption of global IoT technologies. Secondly, the model applies a service perspective, which instead of seeing technology as a technical product, allows analyzing the evolutionary path of its service characteristics.

The second aim of the paper is to provide managerial insights by empirically discussing the model. Two cities that have proven successful in implementing smart PBS services despite quite different local contexts are discussed in the text. One is Styr&Ställin Gothenburg, Sweden, and the other is the Hangzhou Public Bike Service in Hangzhou, China. The aim is not to compare which of them is better than the other, but rather to show that contextual factors can impact the evolution of service characteristics despite identical technologies. From a managerial point of view, it is important for smart PBS planners, operators, and policymakers to consider the pre-existing relationships in the city's public transportation system and the future needs of the users. The best smart PBS scheme is one that best suits the particular city it is located in.

The paper consists of five sections. The introduction of the paper is provided in Sec. 1. Section 2 introduces the development of the characteristics-based approach in service innovation literature and reviews the contexture components in the geography of information technologies. Section 3 integrates two strands of literature and builds the model of public service innovations that utilize IoT, in which the contextual dynamics are highlighted. Section 4 discusses the case studies by using the model. Section 5 concludes the paper with major findings, limitations, and suggestions for future research.

2. Review of Theories

2.1. *The innovation process of public services*

Four approaches have been developed to describe the innovation process of public services (Gallouj and Zanfei, 2013). The *assimilation approach* stems from the technologist tradition, which focusses on the relationship between technology and innovation (Djellal *et al.*, 2013). In contrast, the *demarcation approach* highlights the non-technological contributions of innovation and views service innovation as differing fundamentally from manufacturing (Sundbo, 1997; Coombs and Miles, 2000). The *inversion approach* positions the service sector as a major source of innovation across the economy (Gallouj, 2010). Lastly, a *synthesis approach* has been proposed to embrace both the tangibles and the intangibles (Gallouj, 1998; Coombs and Miles, 2000; Gallouj and Savona, 2009). In this approach, products and services are synthesized as characteristics; it is therefore also called the characteristics-based approach.

The characteristics-based approach is an adequate one to use for public service enabled by IoT. First, IoT applications often comprise both hardware and software as solutions, rather than relying on a single product or service (European Commission, 2015). The characteristics-based approach suits well for such synthesis of products and services. Secondly, public services are responses to public interests, and public authorities naturally take a role in the innovation process. The characteristics-based approach can be used to map innovation process across the private and public sectors, for both technological and non-technological characteristics (De Vries, 2006). Given these two reasons, the characteristics-based approach seems suitable to use.

Section 2.1.1 introduces the development of the characteristics-based approach and its recent operationalization. As the approach is a framework and not a theory, it always needs to be operationalized by theories before it is applied (Windrum and García-Goñi, 2008).

2.1.1. *The development of the characteristics-based approach*

The re-conceptualization of goods and services in the characteristics-based approach is derived from Lancaster, who assumes that "The chief technical novelty lies in breaking away from the traditional approach that goods are the direct objects of utility and, instead, supposing that it is the properties or characteristics of the goods from which utility is derived" (Lancaster, 1966). In other words, Lancaster defines a product (goods or services) as a set of characteristics. This became the starting point of the construction of the Saviotti–Metcalfe framework. In order to describe technological outputs, they operationalized the approach by using technological paradigms and trajectories theory (Dosi, 1982) and defined three sets of characteristics: (1) technical characteristics, i.e. the technical features of the product, (2) service characteristics, i.e. the services performed by the product, and

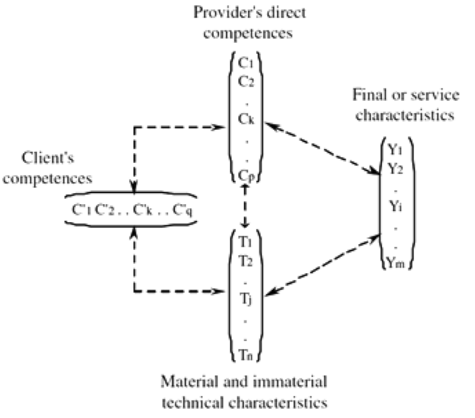

Fig. 1. A general form of the Gallouj and Weinstein framework (1997).

(3) process characteristics, i.e. the methods of producing the product. Their framework laid the foundation for the creation of the Gallouj–Weinstein framework.

Searching for a general theory to explain the service innovation process, Gallouj and Weinstein (1997) proposed a representation of a product/service as a system of characteristics and competences. Their framework (Fig. 1) differs from the Saviotti–Metcalfe framework in several ways. First, the vector of service characteristics is defined as the final users' value instead of as the service performed by the product. This change in definition shifts the focus from "product"-centered to final user-centered.

Secondly, the "competence" mobilized by service providers is added as the fourth set (vector) of the characteristic. *Competence* is defined as the ability and knowledge that are embodied in the technical characteristics. Gallouj and Weinstein reasoned that the pro-vision of service is the result of utilization of tangible/intangible technical characteristics (including competence) and the mobilization of competences by service providers. As related to this change, the set of process characteristics is replaced with the client's competences. The argument for this major operation is due to the simultaneity of service activities. *Simultaneity* refers to the production and consumption of a service occurring at the same time. Therefore, the separation of product and process is no longer a useful analytical tool. Instead, they highlight the clients' participation in service relationships. This phenomenon is particularly true in knowledge-intensive services such as education, consultancy, and health care. The self-service in retail illustrates its extreme form. Gallouj and Weinstein assert that "Whatever term is used (interface, interaction, co-production, 'servuction', socially regulated service relationship, service relationship), this link between service provider and client is the most important element missing from the notion of the product put forward by Saviotti and Metcalfe" (Gallouj and Weinstein, 1997). However, the process characteristics, although being downplayed, do not completely disappear. They are contained in the set of technical characteristics. For this reason, the set of technical characteristics was renamed as material and immaterial technical characteristics.

Given the logic of the framework, innovation is defined as the changes that have an impact on the vector(s). Therefore, the innovation is a process instead of an outcome, and the framework can be used to describe cases at the micro level. The Gallouj–Weinstein framework has been used to map the innovation process for knowledge-intensive services and later also applied to public services such as postal service and health care (Djellal and Gallouj, 2005). In recent years, their framework has been extended to meet the new challenges in service research. De Vries (2006) stressed the *networked effect* of the providers, which responses recent innovation trends in networks of organizations and in the distribution of services. Another extension is the introduction of public authority's role in the framework, done by Windrum and García-Goñi (2008).

2.1.2. *The operationalization of the characteristics-based approach*

It is important to mention that the characteristics-based approach must always be operationalized using theories in the area in which the analysis is applied. The Saviotti–Metcalfe framework is operationalized by using the theory of technological paradigms and trajectories, whereas the Gallouj and Weinstein framework is operationalized by the thesis of co-production between clients and the service providers. In a later application of the approach, a neo-Schumpeterian model of health services innovation was developed by Windrum and García-Goñi (2008). They applied Barras's theory in service innovation (Barras, 1986) and highlighted the evolution of the service innovation over time within an institutional and organizational context.

This operationalization of the characteristics-based approach makes the framework flexible to apply in a variety of service areas. The present paper operationalizes it by using theories of information society from economic geography and highlights the impacts of contextual dynamics on the service characteristics. Section 2.2 develops the set of contextual factors, and then a model of public service innovation using IoT is built in Sec. 3.

2.2. *The contextual dynamics of IoT in public service*

IoT is not a single technology, but rather a coupling of technological advancements in the field of information communication technologies (ICTs). Although there is little research on how to categorize the contextual factors of IoT-driven public services, previous studies on the contextual components of the internet and information technologies can shed some light on the issue.

2.2.1. *Reviewing contextual components of information technologies*

The geography of information technologies has looked into the production and diffusion of the technologies in different geographical scales (Kellerman, 2002; Malecki and Moriset, 2008), as the adoption of new technologies is not an exogenous factor but an inherently social-cultural activity that depends on its contextual setting (Martin, 2002). Information in its pure digital format can be indeed transferred globally in the blink of an eye, while the collecting, processing, and consumption of it are spatially embedded

(Kellerman, 2002). The internet and mobile telephony are likely to adapt or perish when placed in differing contexts as they take on dissimilar attributes that are location-dependent (Wilson *et al.*, 2013). Wilson *et al.* (2013) summarized a spectrum of factors to analyze the contextual components of the information society. These factors include devices, access, culture, and governance.

Devices are the interfaces between the physical and digital worlds, such as a computer, a smart phone, a smart watch, or a virtual reality headset. The usage, availability, and trends of the devices vary across places (Wilson *et al.*, 2013). For example, Arduini *et al.* (2013) analyzed survey data on e-government development from 4,471 Italian municipalities and found that the impact of in-house ICT activities is twice as high as the impact of ICT outsourcing. More emphasis should, therefore, be given to context-specific factors.

Access to information technologies is not only in the presence and absence of the infrastructure. Wilson *et al.* (2013) argue that the cognitive ability and desire to access the digital services, the ownership, and the cost/speed of the access are all factors affecting access. All of these factors are geographically embedded. Research shows that multiple social factors can affect access to the internet, including the user's income, occupation, and level of education, the monopoly internet service provider (ISP) market structure, and the use of English as the official language (Roycroft and Anantho, 2003; Wilson, 2004). For digital public services, access to the service platform is often restricted by passwords and access cards. The physical conditions of a location, such as the climate, topography, and geomorphology, are other potential factors.

Culture can encourage or daunt a certain type of digital technology/service as it is embedded in and contributes to the unique characteristics of a location. Schwanen and Kwan (2008) pointed out that socio-physical context is influencing the usage of digital technologies in our daily life. Previous research shows that cultural factors such as language, ethnicity, and organizational culture are related to the access and usage of information technologies (Welch and Feeney, 2014; Jin and Liang, 2015).

Governance often reflects the policy and regulatory environment of the information technologies. For example, Wentrup *et al.* (2016) discovered that digital policy instruments such as the active level of using universal service funds and low level of tax on computer equipment are significantly correlated with internet access in the 46 countries in Sub-Saharan Africa. Particularly in developing public services, the involvement of the government and public authorities is self-evident.

To sum up, the spectrum of devices, access, culture, and governance has been used to analyze the contextual components of the information technologies. These factors are geographically embedded.

2.2.2. *Categorizing the contextual dynamics of the public services that utilize IoT*

The contextual dimension of IoT is natural as the connected objects and people are always located somewhere on earth. But, the contextual dynamics of public services using IoT reach far beyond their locations. As it is explained in Sec. 2.1, a spectrum of contextual factors can influence the implementation and evolution of service characteristics in a certain location. The paper divides them into three categories: public motives, user preferences, and governance.

Public motives represent why a certain type of public service is needed in a certain place. Although this factor was not mentioned in the literature review, the author argues that it is an important contextual factor for public services that utilize IoT in the innovation process. Admittedly, the innovation of public services is a process of creating new solutions for the "public good," which differentiates it from the pure business logic. That is, rather than profit-seeking, the public purpose is mandatory for implementing such services, and its characteristics should then meet the needs of the public. As we all know, the IoT technologies can be used to serve many different purposes. Thus, the public motives for implementing a new solution at a location can impact their service characteristics.

User preferences impact the evolution of service characteristics in many ways. As discussed in the previous section, the user preferences regarding devices as well as their cognitive ability and desire to access certain types of public services are influential. What is new with IoT is that it allows objects to sense, store, and communicate information in real time and thus provides new ways of doing things. However, this also triggers concerns about data sharing and privacy (Dutton, 2014). A recent study on car-related connected services indicates major regional variations in such concerns. For example, 51% of the consumers in Germany are reluctant to use connected car services due to privacy concern, while the number in China is only 21% (McKinsey and Company, 2014).

Governance of public services relates to the choice of operator and the implementation of the services in general. Public authorities can affect, limit, or push the diffusion of innovations by playing the roles of a service provider, funder of the basic research, consumer, and legislator (Windrum and García-Goñi, 2008). What is more, in the IoT era, the influence of governance and information technologies can be bidirectional. With the development of algorithms, the accumulated information can be mined further to develop new types of services, to improve the existing services, and to advise policymakers, e.g. by revealing patterns in public behavior. Therefore, governance as a contextual factor is related to the implementation of public services that utilize IoT. It includes the choice of operators, funding of policy design, and usage of data.

To summarize, in this paper, public motives, user preferences, and governance are identified as the major contextual dynamics of public service innovation utilizing IoT. Culture can affect the usage of a certain public service, as it represents the unique character of a location. However, such an effect on service characteristics is often not direct. For instance, culture can affect governance and user preferences directly, which in turn are related to the development of service characteristics. The author, therefore, removed culture from the set of contextual dynamics. In the next section, the set of contextual dynamics is used to operationalize the characteristics-based approach.

3. The Contextual Dynamics of Public Service Innovation Using IoT

In this section, the author operationalizes the characteristics-based approach by using the theory of the contextual dynamics of IoT in public services developed in Sec. 2.2. The

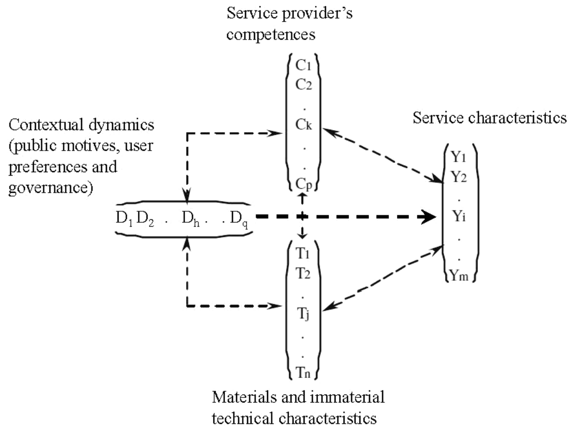

Fig. 2. The contextual dynamics of public service innovations utilizing IoT.

model of public service innovation utilizing IoT is thus built (Fig. 2). The new model highlights the contextual dynamics as a separate vector.

As Fig. 2 shows, the model deviates from the Gallouj and Weinstein framework by replacing the vector of clients' competence with a set of contextual dynamics, i.e. public motives, user preferences, and governance. The contextual dynamics can directly impact the service characteristics. Such changes are due to the different theories that operationalize the characteristics-based approach. The Gallouj and Weinstein framework used co-production theory for operationalization. Therefore, the interactions between clients and service providers are emphasized. When their framework was created, it was mostly referred to knowledge-intensive services such as consultancy, where face-to-face interaction plays a key role in the innovation process. In contrast, in the practice of IoT-driven public services, clients are users in the public space and the number of users is often large, so face-to-face interaction between users and the service providers is less common. The users' impact on the service characteristics is expressed by their preferences. Therefore, in the new model, the vector of clients' competences is taken away. Since the co-production theme is no longer the focus in the new model, there is no need to differentiate between "final" and "intermediary" service characteristics. Thus, it is enough to use service characteristics to represent the final users' value.

In this model, vector [**Y**] represents service characteristics, which are defined as the final users' value. For IoT-driven public services, the exact value varies by case. For example, the smart PBS scheme as a technical product offers short-term, point-to-point, self-service public bike rentals in the city center area. But for the final users, the value can be mobility and convenience, i.e. traffic congestion avoidance or a solution to the "last mile" problem. For tourists, it can be the access to a flexible public transportation mode at a low cost.

Vector [**C**] represents service provider's competences, the mobilization of which can impact the service characteristics. Service provider can be composed of multiple providers or a single provider, who can be private actors, public authorities, and quasi-governmental actors. When developing public services, service provider works together with public authorities in the public procurement processes.

Vector [**T**] is the material and immaterial technical characteristics. As the model is built for public service innovations that utilize IoT, the technical characteristics are related to IoT technologies. IoT, generally speaking, is a kind of network that has been extended to include the networks of objects and people's activities based on the Internet, the common technical characteristics can be thus described as automation and telematics (Xu, 2012). For a specific IoT service platform, the technical characteristics can vary to serve for some specific purpose (e.g. the electronic locking rack can be remotely controlled). Process characteristics that are dependent on contexts are replaced by the contextual dynamics, e.g. governance.

Vector [**D**] refers to the contextual dynamics, including public motives, user preferences, and governance. As mentioned in Sec. 2.2.2, these factors are embedded in place, shaping the implementation and evolution of public services that utilize IoT. Understanding these factors is crucial in order for the providers to effectively plan and manage the services.

To conclude, the model of public service innovations utilizing IoT includes four sets of characteristics: (1) service characteristics, i.e. the final users' value; (2) the service provider's competences; (3) contextual dynamics, i.e. public motives, user preferences, and governance; and (4) material and immaterial technical characteristics.

In the next section, this model is used to analyze the case of smart PBS schemes in different locations. As the model is operationalized by the theory of contextual dynamics, the impacts of the contexts on the implementation and evolution of the service characteristics are highlighted. Thus, the paper answers the question raised at the beginning of the paper: Does geography still matter for the implementation and evolution of globally identical technologies like IoT?

4. Empirical Analysis

The empirical analysis of the smart PBS services is performed by using the new model (Fig. 2). The smart PBS schemes in the two studied cities are introduced in Sec. 4.1. Section 4.2 gives a summary of the evolution of service characteristics in each case. Section 4.3 offers a detailed analysis of the causes of such differences in the evolution of service characteristics.

The empirical material was collected through interviews and field visits. The first field visit and the set of interviews were conducted March–April 2014 in Hangzhou, China and Gothenburg, Sweden. The second round of interviews took place in December 2016. Each interview lasted 45–60 min. A list of the interviews conducted is provided in Appendix A, and the interview questions can be found in Appendix B. Doing two rounds of interviews helped provide an overview of the evolution of service characteristics over time.

4.1. *The smart PBS schemes in Gothenburg and Hangzhou*

PBS is neither a new idea nor a new practice. Prior attempts could not be sustained and scaled up because the systems were not efficient enough to balance the costs of operation on a large scale (DeMaio, 2009). The current generation, i.e. smart PBS schemes, is driven by IoT and can, therefore, be operated large scale at a manageable cost. The service often allows users to rent and return a bike between different stations for a short period of time in the city area. The first 30–60 min are often free of charge. Velo'v in Lyon is the first smart PBS scheme to receive considerable attention. In 2007, Paris introduced its smart PBS service, which soon became a huge success. Since then, the smart bike sharing scheme has really taken off and diffused rapidly around the world. By April 2013, there were an estimated 535 schemes with 517,000 bicycles in 49 countries (Earth Policy Institute, 2013). By 2015, the number of cities with a smart PBS scheme had climbed to over 700 (The Economist, 2015), and by 2016, more than 800 cities around the world were operating such services (Fishman, 2016). The two cases analyzed in the paper are Styr&Ställin Gothenburg and Hangzhou Public Bike Service in Hangzhou. As mentioned in Sec. 1, the aim is not to compare the systems and determine which one is better. Instead, the reason for using cases with different contextual backgrounds is to illustrate the impacts of the contextual dynamics on service characteristics.

Styr&Ställin was launched by the municipal government in August 2010. It is the second largest bike sharing scheme in Sweden and has gained increasing popularity among its users. It generated 11,595 trips in 2010, and by 2015, the number had reached 727,460 trips made by 29,203 users. By the end of 2016, the system had a total of over 1,000 operational bikes and 68 stations distributed across the city center (Mattsson, 2016). The governance of the smart PBS scheme in Gothenburg can be described as a type of private intervention of public services (Beroud and Anaya, 2012). The municipal government is the initiator and host, and the Urban Transport Administration is executing the project, while the installation, operation, and maintenance are carried out by the private outdoor advertising company JCDecaux. The municipality offers outdoor advertising spaces to JCDecaux in exchange for its construction, operation, and maintenance work over the contract period. The Urban Transport Administration plans, monitors, and evaluates the services. The whole system including the physical infrastructures and data gathered from the docks and users' accounts are owned by JCDecaux; municipality owns the brand "Styr&Ställ" (Åker, 2014; Lind, 2014; Mattsson, 2016).

The city of Hangzhou runs China's first smart PBS scheme and is also the second largest system in the country. Influenced by the success in Lyon and Paris, the municipal government decided to introduce the smart PBS service in 2008. In May of that year, the first 61 stations with 2,800 bikes opened and were immediately well received by both citizens and tourists (Liu, 2014). By the end of 2016, the city had 84,600 bikes and 3,378 stations operating in the city center and sub-districts, on average generating 320,000 rentals per day (Liu, 2016). The Hangzhou smart PBS scheme is managed as the commercial operation of public welfare services. The common method "government buys services" represents the socialist principle of market operation for non-profit, welfare public services (Liu, 2014; Zhang, 2014). The municipal government is the initiator and host, and the Hangzhou public transport group (a fully state-owned company) executes the project. The Hangzhou public transport group has set up a solely owned subsidiary, Hangzhou bike sharing company, to operate the service. To make the business sustainable, it then set up a joint-stock company, GST Tech, to export the system to other Chinese cities as an additional source of income. During the contract period, the Hangzhou bike sharing company is the operator and owner of the whole system, including the physical infrastructure and all data gathered from the docks and users' accounts. The Hangzhou public transport group plans, monitors, and evaluates the system and is in charge of all contracts. The operator is responsible to build, operate, and maintain the system and all services. As over 96% of the usage is free of charge, the revenues from the users are very low (Liu, 2014, 2016). The initial investment (infrastructure and all the investments in bikes, etc.) is from government subsidies, and the aim is to make the business self-sufficient in the long run. Apart from the direct subsidies, the operator generates revenue by renting out advertising space and kiosks as well as by offering consulting services and exporting the technical system to other cities (Liu, 2014, 2016; Zhang, 2014; Shi, 2014).

4.2. *Summary of the evolution of service characteristics in each case*

The evolution of smart PBS service characteristics differs between Gothenburg and Hangzhou. Table 1 summarizes the differences in service characteristics.

The major values for the users are low cost, safety, convenience, and flexible mobility. The smart PBS services offer the missing link between existing points of public transportation and desired destinations (Midgley, 2011). The major technological characteristics include electronic locking racks to remotely control the locks, mobile/web applications to show real-time availability of bikes at nearby stations, computers at the stations for digital payment processing, and information communication systems to link everything together that administrative tasks can be run at the back office (Åker, 2014; Liu, 2014; Shi, 2014; Zhang, 2014). Many personalized services can be delivered via the virtual maps of mobile applications for smart PBS schemes. The users can have real-time information about the availability of bikes based on their locations. The subscribers can check their account information and optimize routines based on their own historical record. Users can also report problems and give feedbacks via mobile applications. As the virtual maps in the web or mobile applications can have multiple layers, more locational-based services can be added.

4.3. *Discussion of the differences in service characteristics*

4.3.1. *Contextual dynamics*

4.3.1.1. The impacts of public motives on the service characteristics of mobility and convenience (virtual maps, kiosks)

Besides the shared public motives of promoting sustainability and enhancing the city image, the two cities have their separate stories about why the smart PBS schemes are demanded.

The urban area of Gothenburg is about 203 km^2 in size and has a population of over half a million (Statistics Sweden, 2015). The city is just the right size for biking. The size of the city center is neither too small (thus pedestrians are favored) nor too large (subways and

Table 1. A summary of the major differences in service characteristics of the smart PBS schemes in Gothenburg and Hangzhou (author's own elaboration based on the interviews and field visits in 2014 and 2016).

Differences in service characteristics	Gothenburg	Hangzhou
Mobility	Optimizing travel time in the city center as a complementary public transportation mode	Traffic congestion avoidance; map for bicycle tours; in 2016, mountain bikes were made available at some stations at a higher fee in order to diversify the service for tourists
Convenience (access and payments)	Initially for seasonal users with the electronic wallet on any pre-existing card that includes this function; for casual users with the 3-day card and the tourist card; from 2016, the regional public transportation card can be used by seasonal users, and a company card was also made available	Initially with the PBS Z card, citizen card, and city traffic card; in 2016, mobile payment was launched
Convenience (virtual maps)	Same mobile application in other cities[a]; the virtual map can show service points for pumps and bicycle lanes[b]	The virtual map can show parking, taxi services, and information about other public transportation modes[c]; mobile tourist service is planned to be integrated on the virtual map
Safety (anti-theft)	Electronic locking racks	Electronic locking racks and monitoring cameras at stations
Convenience (on-station kiosk)	No	Yes
Safety (insurance)	Included in home and credit card insurance	Special insurance is included with use
Safety (Protection of privacy)	EU directive on data protection from 2016	No formal laws

Notes: [a]The mobile application refers to Cykelstaden (developed by Urban Transport Administration).
[b]The mobile application refers to AllBikesNow (developed by JCDecaux).
[c]The web application can be accessed at http://www.hzbus.cn/ (developed by Hangzhou City).

inter-city trains are fully developed). The current public transportation modes, i.e. trams, buses, and ferries, are not sufficient to provide convenient, flexible point-to-point service in the city center. Some areas suffer from a lack of public transportation nodes (Forsberg, 2016; Mattsson, 2016). Thus, the public motive of using bicycling as a complementary mode has a long history (Åker, 2014). The smart PBS provides an even more convenient alternative — users do not need to bring their own bikes and worry about theft. The distance between two PBS stations is no more than 300 m (Forsberg, 2016), which gives users great flexibility in choosing departure and destination points.

The core city area of Hangzhou covers 4,876 km^2 and has a total population of over 7 million (Hangzhou Statistics Bureau, 2015). In contrast to Gothenburg, the city has experienced rapid urbanization and population growth in recent decades. Since the late 1990s, the core urban area has expanded sevenfold and the peri-urban area more than fourfold (Spiekermann *et al.*, 2013). The population has increased from 1.1 million to 4.2 million in the core urban area (Hangzhou Statistics Bureau, 1990–2015). The rapid urbanization has put immense pressure on the public transportation system. In recent years, the congestion problems have escalated due to the fast growth in car use. Thus, one important motive for Hangzhou to develop smart PBS scheme was to manage the public transport demand (Liu, 2014). Compared with Gothenburg, service characteristics such as congestion avoidance and a solution to the last mile problem are more visible in Hangzhou. The smart PBS scheme is therefore integrated with the other public transportation modes, such as subways and buses, in the planning of bike station sites. The virtual maps online can show information for most of the city's public transportation modes, enabling users to switch between them easily.

The city of Hangzhou is a world-renowned tourist destination with the beauty of West Lake surrounded by mountains on three sides, and the smart PBS scheme has been developed with this in mind. Tourist information is co-located with the kiosk service at many bike stations. Bicycle tour maps have been designed to help tourists get the most out of the smart PBS scheme, and digital versions are going to be integrated with the virtual navigation services. In October 2016, 100 mountain bikes were introduced at select service points around West Lake with an aim to diversify the service to meet the changing needs of the younger users and tourists (Liu, 2016).

As for the future expansion of the smart PBS schemes, both cities are going to increase the density of the stations in the busiest areas. In Gothenburg, the plan is also to expand the service to include the island of Hisingen (Mattsson, 2016). Hisingen forms the northern part of the city with a share of over 20% of the population. For bicyclists, the island is well connected with the mainland by a bridge and free ferries, so demand for such an extension of the PBS scheme is natural. In the last eight years, the smart PBS scheme in Hangzhou has expanded from only central areas to sub-districts and adjacent cities 10–80 km from the city center (Liu, 2014, 2016). Not all locations have the same operator, so a challenge for the future will be to integrate the different service systems.

4.3.1.2. Impact of user preferences on the service characteristics of convenience (access and payments) and safety (anti-theft)

The smart PBS services target several user groups, including seasonal city commuters, tourists, and casual users, and there are also several types of access cards in both cities. Due to path dependency, the means of access and payments are often built upon the existing systems in a city and are also influenced by the changing preferences of the (new) users.

Sweden is a world leader when it comes to card payments (Segendorf and Wretman, 2015). Gothenburg's public buses have not accepted cash payments for years. When designing the access and payment system for the PBS scheme, there is an aim not to create more cards (Forsberg, 2016). Therefore, seasonal users pay using the electronic wallet on any pre-existing card that includes this function. Since 2016, this function is available via the regional public transportation card. The casual users can buy a 3-day pass on the bike station computers. The tourists can use Gothenburg City Card to get access to the PBS service together with their debit/credit cards. At the request of many companies in the city, a seasonal subscription under the name of a company instead of a person has been introduced.

The Chinese are not as dependent on card payments as Swedes, paving the way for rapid adoption of mobile payments. In the city of Hangzhou, there are three types of access cards. The *shimin* (citizen) card and the *jiaotong* (city traffic) card are the most frequently used cards for purchases of public services. These two cards are the most convenient ways to access the smart PBS services. There is also a special card (Z card) used only for the smart PBS services, but the users must buy it in advance at the service points. Due to the growing popularity of mobile payments in China, a new type of access was launched in 2016. Supported by online payment platforms such as Wechat and Alipay, users can scan a QRcode on the bike and make the payment directly on any mobile phone.

Besides the electronic-locking racks, Hangzhou uses networked cameras at bike stations as an extra anti-theft method. These cameras supplement the city's public security system. Although the main streets in Hangzhou are equipped with the camera monitoring system, some of the public bike stations are on branched-off roads. The networked cameras at these bike stations add additional security to the city's monitoring system.

4.3.1.3. Impacts of governance on the service characteristics of convenience (virtual maps and kiosk), safety (insurance), and privacy

The specific policy for the city government of Hangzhou to guide the planning of the smart PBS scheme has positive outcomes. A major benefit is the integration of various services such as parking, taxis, tourist's information, and other public transportation modes on the same virtual map. In Gothenburg, the Urban Transport Administration is in charge of planning bicycle lanes and supporting services such as free pump sites. Thus, these functions are integrated into the virtual maps on its mobile application Cykelstaden.

The difference in mode of governance impacts the financing of the services. This is why bike station kiosk services are available in Hangzhou but not in Gothenburg. In Gothenburg, other outdoor advertising spaces are offered to JCDecaux in exchange for operating the PBS scheme, and hence no advertisements are displayed on the bikes or at the stations. In Hangzhou, major financial support comes from the government; yet the operator is encouraged also to find ways to balance the cost and income in other ways. Therefore, the spaces on bikes and at stations become good sources of income from the renting out of advertisement space and kiosks (Liu, 2016).

The differences in insurance between the studied PBS schemes are due to path dependency that is related to governance in general. The users in Gothenburg are already covered via their home or credit card insurance. There is, therefore, no need to provide a separate insurance. In contrast, in Hangzhou, there is no corresponding insurance coverage, and hence it is included in the smart PBS scheme.

Time will tell if there is convergence or divergence on the handling of privacy issues. The major difference is in the legal framework. In Europe, the EU General Data Protection Regulation (GDPR) went into force in May 2016, but will not be adopted as national law in its member states until 2018. It standardizes and sets strict rules for the collection and usage of personal data for all member states. China has not yet adopted this type of law.

In both cases, at present, it is currently the operator who owns all data. During the interviews, the operators claimed that they do not use the data for purposes other than to improve the PBS services and all data are anonymized prior to any analysis (Lind, 2014; Liu, 2014, 2016; Forsberg, 2016; Mattsson, 2016), e.g. to optimize the locations of the stations, the number of bikes at each station, and the reshuffling of bikes between busy and idle stations. In Gothenburg, the operator uses the data of seasonal users to send out user surveys, and the results are shared with the city authorities (Mattsson, 2016). However, since GDPR will not apply in the Swedish national legal system until 2018, there is no evidence so far regarding its influence. In Hangzhou, the operator plans to use big data technologies to measure the current services better and to predict future needs (Liu, 2016).

As shown earlier, the governance structure affects the choice of operator. In Gothenburg, the operator is the outdoor advertising company JCDecaux. In Hangzhou, the government created a state-owned entity to operate the project, the Hangzhou bike sharing company. The influence of the providers' competence on the service characteristics is discussed in the next section.

4.3.2. *The competence of the operators*

4.3.2.1. JCDecaux

JCDecaux has a long history of cooperating with the city of Gothenburg to provide public services such as public toilets and bus stations (Forsberg, 2016), although the company's main business area is outdoor advertisement. It also has a long history of operating smart PBS schemes in Europe. According to statistics on 51 smart PBS schemes in Europe, JCDecaux and ClearChannel are the two top operators across Europe (OBIS, 2011). JCDecaux is the operator of the Velo'v scheme in Lyon. Thus, the service provider has accumulated substantial competence from operating public services with the city authorities in Gothenburg and running smart PBS schemes in other European cities. The institutional framework of such a public–private partnership is regulated at the EU supranational level via service concession according to Procurement Directive 2004, which strengthens JCDecaux's competence in the internationalization process of their smart PBS services. The experiences learned from different cities can be used to improve the company's service offerings (Forsberg, 2016).

4.3.2.2. The Hangzhou bike sharing company

The Hangzhou Public Transport Group is a state-owned enterprise and a quasi-governmental actor, and this dual role has enabled it to create a state-owned company, the Hangzhou bike sharing company, to operate the scheme. Under such a structure, the public authority has more control over the operators not only by contracting power but also by the hierarchy power. In contrast, in Gothenburg, the public authority only has the contracting power, which leads to less control over the operator. This dual role also enabled the creation of a semi state-owned company, GST Tech, to export the system to other cities in China as an extra source of income, which increases the diffusion of innovation. In contrast, in Gothenburg, this role is carried out by the private actor. Thirdly, the Hangzhou

Public Transport Group is responsible for the planning and management of the city's public transportation system, which implies fewer barriers to incorporating the PBS scheme in the entire public transportation system. In contrast, such integration has been difficult in Gothenburg. Moreover, as different cities may have different PBS operators, this could be a barrier to future integration of PBS schemes at a regional level (Åker, 2014).

5. Conclusions and Implications

The paper concludes that the contextual factors such as public motives, user preferences, and governance can impact the implementation of smart PBS schemes and the evolution of their service characteristics. A model that explicitly includes these three contextual factors is proposed to analyze the innovation process of public services utilizing IoT. The model has two major contributions. First, the emphasis on the local contexts calls for a human-centered approach to the deployment of IoT applications. As the technical characteristics of IoT are rather identical across the globe, there is a tendency to ignore the place in which it is adopted. The proposed model stresses the particularity of a place and the needs of people during the process of adopting pervasive IoT technologies. Secondly, the new model applies a service perspective to analyze the adoption of information technologies. Thus it can trace the evolutionary path of the service characteristics at different places, even though the technical characters are the same.

The case study provides management insights for PBS planners, operators, and policymakers on different ways of implementing PBS services such as for the choice of the operator, the ownership structure, financing method, and the policy design. The results show that a "one size to fit all" scheme does not exist, and the best smart PBS scheme is the one that adapts to the needs of the particular city it is located in. The proposed model provides a practical tool to review the evolution of the service characteristics and the impact factors such as technical and non-technical elements including the contextual dynamics.

As the model is developed by the general theories of information technologies, it can be applied to analyze other types of digital public service platforms than only the IoT services. However, it is limited to the analysis of public services that involves the public authorities. During these years, there has been a surge of private bike sharing schemes in China such as ofo and mobike. They are market-driven with no or little government regulation. These cases do not apply to the present model. But it raises the fundamental concern about the privacy and data protection of the users. Especially under the situation that data are in the hand of private actors with powerful data analytical capabilities such as Tencent and Alibaba, who can then utilize these data for profit-seeking business activities. It puts forward the question of what kind of role should the public sectors and the authorities take in regulating the private bike sharing schemes and hence digital services in general.

The issue of privacy is closely related to the protection of data, and the legal framework of data protection is rather fragmented in the world. As IoT technologies enable automated data transfer, it requires additional security measures, especially when data contain sensitive personal information. For EU member states, GDPR entered into force in May 2016 and shall apply from 25 May 2018. China lacks such legal regulations so that the protection of data relies on informal institutions such as business ethics and paternalistic Confucian values in the authoritarian convention. In the Hangzhou scheme, the operator is state-owned, which makes the case more complicated because in theory a state-owned entity is owned by the people. In this respect, the data belong to people, and in practice, this means that it relies on the goodness of the authorities. Is there a global convergence around the EU standard? It still takes time to see. This would be an interesting question to address in future research.

Appendix A. The List of the Interviews

Name	Role	Organization	Date of intervie	Type of intervie
Caroline Mattsson	Project Leader	Urban Transport Administration, Gothenburg, Sweden	20 December 2016	Face-to-face
Jonas Åker	Project Leader	Urban Transport Administration, Gothenburg, Sweden	14 April 2014	Face-to-face
Robin Forsberg	Bicycle Technician	JCDecaux, Sweden	22 December 2016	Face-to-face
Stefan Lind	Operation Manager	JCDecaux, Sweden	10 April 2014	Face-to-face
Chaoyong Liu	Deputy Manager	Hangzhou Public Bike Service, China	20 December 2016	On telephone
Chaoyong Liu	Deputy Manager	Hangzhou Public Bike Service, China	04 March 2014	Face-to-face
Liqiang Zhang	General Manager	Hangzhou Green Smart Traffic Tech Co., Ltd.	10 March 2014	Face-to-face
Lei Shi	Executive Vice President	WASU Group, China	14 March 2014	Face-to-face
Yuhang Cao	Deputy Manager	Jiaxing Public Bike Service, China	07 March 2014	Face-to-face

Appendix B. Interview Questions

For the first round of interviews, the questions are structured according to the scheme framework provided by *Optimising Bike Sharing in European Cities*, A Handbook (OBIS, 2011). The interview questions were structured in four parts: (1) the aims and objectives of the scheme, (2) the physical and technology of the scheme, (3) the governance structure of the scheme (who is involved, what are the roles and responsibilities of each actor, and how do the actors work with each other?), and (4) the policy designs for the scheme (if any at the city, regional, and national levels). The information on the physical design and technology (part 2) is operated as a control factor to confirm that the technology parts similar in both cases. The second round of interviews was designed to update the development of the schemes and the evolution of the service characteristics. Additionally, as the EU data protection law is coming into force in 2016, a question about its impacts on the ownership and management of the data was added.

References

Arduini, **Davide**, **Mario Denni**, **Matteo Lucchese**, **Alessandra Nurra, and Antonello Zanfei.** 2013. "The Role of Technology, Organization and Contextual Factors in the Development of E-Government Services: An Empirical Analysis on Italian Local Public Administrations." *Structural Change and Economic Dynamics*, 27: 177–189.

Barras, **Richard.** 1986. "Towards a Theory of Innovation in Services." *Research Policy*, 15(4): 161–173.

Behrendt, **Frauke.** 2016. "Why Cycling Matters for Smart Cities. Internet of Bicycles for Intelligent Transport." *Journal of Transport Geography*, 56: 157–164.

Beroud, **Benoît, and Esther Anaya.** 2012. "Private Interventions in a Public Service: An Analysis of Public Bicycle Schemes." In *Transport and Sustainability*, eds. Stephen Ison and Jon Shaw, pp. 269–301. Britain: Emerald Group Publishing Limited.

Bonnette, Brittany. 2007. "The Implementation of a Public-Use Bicycle Program in Philadelphia." University of Pennsylvania, Urban Studies Program. http://repository.upenn.edu/senior_seminar/12/?utm_source=repository.upenn.edu%2Fsenior_seminar%2F12&utm_medium=PDF&utm_campaign=PDFCoverPages.

Coombs, **Rod, and Ian Miles.** 2000. "Innovation, Measurement and Services: The New Problematique." In *Innovation Systems in the Service Economy*, eds. Rod Coombs and Ian Miles, pp. 85–103. US: Springer.

DeMaio, **Paul.** 2009. "Bike-Sharing: History, Impacts, Models of Provision, and Future." *Journal of Public Transportation*, 12(4): 41–56.

De Vries, **Erik J.** 2006. "Innovation in Services in Networks of Organizations and in the Distribution of Services." *Research Policy*, 35(7): 1037–1051.

Djellal, Faridah and Faïz Gallouj. 2005. "Mapping Innovation Dynamics in Hospitals." *Research Policy*, 34(6): 817–835.

Djellal, **Faridah**, **Faïz Gallouj, and Ian Miles.** 2013. "Two Decades of Research on Innovation in Services: Which Place for Public Services." *Structural Change and Economic Dynamics*, 27: 98–117.

Dosi, **Giovanni.** 1982. "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change." *Research Policy*, 11(3): 147–162.

Dutton, **William H.** 2014. "Putting Things to Work: Social and Policy Challenges for the Internet of Things." *info*, 16(3): 1–21.

Earth Policy Institute. 2013. "Countries with Bike-Sharing Programs." http://www.earth-policy.org/?/data_center/C23/(accessed January 5, 2017).

European Commission. 2015. "Benchmark Study for Large Scale Pilots in the Area of Internet of Things—Digital Agenda for Europe." http://ec.europa.eu/digital-agenda/en/news/benchmark-study-large-scale-pilots-area-internet-things (accessed January 5, 2017).

Fishman, **Elliot.** 2016. "Bikeshare: A Review of Recent Literature." *Transport Reviews*, 36(1): 92–113.

Fishman, **Elliot**, **Simon Washington, and Narelle Haworth.** 2013. "Bike Share: A Synthesis of the Literature." *Transport Reviews*, 33(2): 148–165.

Fishman, **Elliot**, **Simon Washington**, **Narelle Haworth, and Armando Mazzei.** 2014. "Barriers to Bikesharing: An Analysis from Melbourne and Brisbane." *Journal of Transport Geography*, 41: 325–337.

Fishman, **Elliot**, **Simon Washington**, **Narelle Haworth, and Angela Watson.** 2015. "Factors Influencing Bike Share Membership: An Analysis of Melbourne and Brisbane." *Transportation Research Part A: Policy and Practice*, 71: 17–30.

Gallouj, **Faïz.** 1998. "Innovating in Reverse: Services and the Reverse Product Cycle." *European Journal of Innovation Management*, 1(3): 123–138.

Gallouj, **Faïz.** 2010. "Services Innovation: Assimilation, Differentiation, Inversion and Integration." In *The Handbook of Technology Management*, ed. Hossein Bidgoli, pp. 989–1000. New Jersey: John Wiley and Sons.

Gallouj, **Faïz, and Antonello Zanfei.** 2013. "Innovation in Public Services: Filling a Gap in the Literature." *Structural Change and Economic Dynamics*, 27: 89–97.

Gallouj, **Faïz, and Maria Savona.** 2009. "Innovation in Services: A Review of the Debate and a Research Agenda." *Journal of Evolutionary Economics*, 19(2): 149–172.

Gallouj, **Faïz, and Olivier Weinstein.** 1997. "Innovation in Services." *Research Policy*, 26(4): 537–556.

Hangzhou Statistics Bureau. 1990–2015. "Urban Registered Population and Total Population" (1978–2015). http://www.hzstats.gov.cn/web/tjnj/nj2016/showChapter.aspx?id=2-03 (accessed January 16, 2017).

Hangzhou Statistics Bureau. 2015. "Land Area and Population Density." http://www.hzstats.gov.cn/web/tjnj/nj2016/showChapter.aspx?id=1-02 (accessed January 16, 2017).

Jin, **Haihe, and Jian Liang.** 2015. "How Should the Chinese Government Provide Information Services for Mongol Ethnic Minority." *Government Information Quarterly*, 32: 82–94.

Kellerman, **Aharon.** 2002. *The Internet on Earth: A Geography of Information*. Sussex: John Wiley & Sons.

Lancaster, **Kelvin J.** 1966. "A New Approach to Consumer Theory." *Journal of Political Economy*, 74(2): 132–157.

Malecki, **Edward J., and Bruno Moriset.** 2008. *The Digital Economy: Business Organization, Production Processes, and Regional Developments*. New York: Routledge.

Martin, **Ron.** 2002. "Institutional Approaches in Economic Geography." In *A Companion to Economic Geography*, eds. Trevor Barnes, Jamie Peck, and Eric Sheppard, pp. 77–94, Oxford: Blackwell Publishing Ltd.

Mátrai, **Tamás, and János Tóth.** 2016. "Comparative Assessment of Public Bike Sharing Systems." *Transportation Research Procedia*, 14: 2344–2351.

McKinsey and Company. 2014. "Connected Car, Automotive Value Chain Unbound." https://www.mckinsey.de/files/mck_connected_car_report.pdf (accessed January 5, 2017).

Midgley, **Peter.** 2011. "Bicycle-Sharing Schemes: Enhancing Sustainable Mobility in Urban Areas." *United Nations Department of Economic and Social Affairs*, pp. 1–12.

Mrkajić, **Vladimir, and Isabelle Anguelovski.** 2016. "Planning for Sustainable Mobility in Transition Cities: Cycling Losses and Hopes of Revival in Novi Sad, Serbia." *Cities*, 52: 66–78.

OBIS. 2011. *Optimising Bike Sharing in European Cities*. http://www.carplus.org.uk/wp-content/uploads/2015/09/Obis-Handbook.pdf (accessed January 5, 2017).

Roycroft, **Trevor R., and Siriwan Anantho.** 2003. "Internet Subscription in Africa: Policy for a Dual Digital Divide." *Telecommunications Policy*, 27(1): 61–74.

Saviotti, **Pier-Paolo, and John Stanley Metcalfe.** 1984. "A Theoretical Approach to the Construction of Technological Output Indicators." *Research Policy*, 13(3): 141–151.

Schwanen, **Tim, and Mei-Po Kwan.** 2008. "The Internet, Mobile Phone and Space-Time Constraints." *Geoforum*, 39(3): 1362–1377.

Segendorf, **Björn, and Anna-Lena**, **Wretman.** 2015. "The Swedish Payment Market in Transformation." *Sveriges Riksbank Economic Review*, 3: 48–68.

Segui Pons, **Joana Maria**, **Jaume Mateu Llado**, **Maurici Ruiz Perez, and Maria Rosa Martinez Reynes.** 2016. "Bike-Sharing Schemes and Sustainable Urban Mobility. An Analysis in the City of Palma (Mallorca, Balearic Islands)." *Boletin de la asociacion de geografos espanoles*, 71: 505–510.

Spiekermann, **Martin**, **Youjoun He**, **Jianjun Yang**, **Irene Burkhardt**, **Fei Yan**, **Xin Yi, and Stephan Pauleit.** 2013. "Hangzhou: Fast Urbanisation and High Population Growth." In *Peri-Urban Futures: Scenarios and Models for Land Use Change in Europe*, eds. Kjell Nilsson, Stephan Pauleit, Simon Bell, Carmen Aalbers and Thomas Nielsen, pp. 307–337. Berlin, Heidelberg: Springer.

Statistics Sweden. 2015. "Population in the Country, Counties and Municipalities on 31/12/2015 and Population Change in 2015." http://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/yearly-statistics–municipalities-counties-and-the-whole-country2/population-in-the-country-counties-and-municipalities-on-31122015-and-population-change-in-2015/ (accessed January 16, 2017).

Sundbo, **Jon.** 1997. "Management of Innovation in Services." *The Service Industries Journal*, 17(3): 432–455.

The Economist. 2015. "Cities Are Starting to Put Pedestrians and Cyclists before Motorists. That Makes Them Nicer — and Healthier — to Live in." *The Economist*, September 5.

Weber, **K. Matthias**, **Barbara Heller-Schuh**, **Helge Godoe, and Rannveig Roeste.** 2014. "ICT-Enabled System Innovations in Public Services: Experiences from Intelligent Transport Systems." *Telecommunications Policy*, 38(5–6): 539–557.

Welch, **Eric W., and Mary K. Feeney.** 2014. "Technology in Government: How Organizational Culture Mediates Information and Communication Technology Outcomes." *Government Information Quarterly*, 31(4): 506–512.

Wentrup, **Robert**, **Xiangxuan Xu**, **H. Richard Nakamura, and Patrik Ström.** 2016. "Crossing the Digital Desert in Sub-Saharan Africa: Does Policy Matter?" *Policy and Internet*, 8(3): 248–269.

Whiteman, **Gail.** 2014. "The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism." *Nature*, 511(7508): 152–154.

Wilson, **Ernest J.** 2004. *The Information Revolution and Developing Countries*. Cambridge: MIT Press.

Wilson, **Mark I.**, **Aharon Kellerman, and Kenneth E. Corey.** 2013. *Global Information Society: Technology, Knowledge, and Mobility* (*Human Geography in the Twenty-First Century: Issues and Applications*). Maryland: Rowman & Littlefield Publishers, Inc.

Windrum, **Paul, and Manuel García-Goñi.** 2008. "A Neo-Schumpeterian Model of Health Services Innovation." *Research Policy*, 37(4): 649–672.

Xu, **Xiangxuan.** 2012. "Internet of Things in Service Innovation." *The Amfiteatru Economic Journal*, 14(6): 698–720.

Yang, **Jiawen**, **Junxian Chen**, **Meng Zhou, and Zhenmin Wang.** 2015. "Major Issues for Biking Revival in Urban China." *Habitat International*, 47: 176–182.

Zhou, **Haiying**, **Kun-Mean Hou**, **Decheng Zuo, and Jian Li.** 2012. "Intelligent Urban Public Transportation for Accessibility Dedicated to People with Disabilities." *Sensors*, 12(8): 10678–10692.

IV

Supranational Resource Concertation – The role of public policy for new industrial path creation in the European Union

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Abstract

How does public policy facilitate the emergence of the new technology-based industry on the supranational level? In recent years the role of policies for new industry formation has received much attention. Most studies in economic geography, however, are focused on regional specific policies within the national context. This paper contributes to the debate by inserting a supranational European Union (EU) dimension. Theoretically, it contributes to the theory development by proposing an analytical framework on the role of EU policies for path creation. By analysing the evolution of Internet of Things (IoT) policy-making in the EU during the last decade, the study reveals that supranational resource concertation has played an essential role of the EU institutions to unleash the potential of IoT in Europe. Empirically it is the first study to provide a holistic picture of IoT policy development within the framework of intergovernmental cooperation at the EU level. Policy implications contribute to the construction of an evolutionary alternative for public policy to adapt to the non-linear path of embryonic industries.

Keywords

Path creation; Internet of Things; digital single market; European Union; early industry creation

1. Introduction

The promises and pitfalls of emerging technology-based industries present challenges for policymakers worldwide. A key challenge is the non-linear nature of embryonic industries (Karnøe and Garud, 2012). Evolutionary Economic Geography (EEG) and innovation studies have made significant contributions to tackling this problem. They understand the process of new industrial path creation as evolutionary and place-dependent (Asheim et al., 2011; Asheim and Gertler, 2005; Boschma and Frenken, 2011; Coenen et al., 2016; Martin and Martin, 2016; Tödtling et al., 2013).

The current debate on the role of policy in path creation, however, has paid little attention outside of its regional/national foci, although "pursuing such a region-specific policy is not to say that regional policy should rely on the region itself" (Asheim et al., 2011:900). This paper aims to contribute to the theory development by inserting a supranational EU dimension, i.e., proposing an analytical framework on the role of EU policies for path creation. The theoretical development is supported by a case study on the evolution of Internet of Things (IoT) policy-making in the EU. Thus the study also fills up the empirical gap on how policy actions from the supranational EU dimension can facilitate the path creation of embryonic industries. This case study provides policy implications of adapting public policies to the non-linear path of emerging technology-based industries.

The rise of the IoT is an industry driven phenomenon and supported by a range of policy initiatives by the world's leading economies. A decade ago, IoT came into the limelight at the EU policy debate with high expectations for growth, deep concerns about privacy, security, and ethical issues in a complex global competitive landscape. When the EU launched its first action plan for IoT in 2009, it was rather a technological vision than market reality: regulations were largely absent, user preferences had not emerged, and the industrial value chain was in its nascent phase. This situation required IoT policy-making to deal with extraordinary uncertainties and change. Although not possessing exclusive competence within the field of technology policy, but rather the shared competence in which this exercise, according to the Treaty, "shall not result in Member States being prevented from exercising theirs" (TFEU art 4:3), the EU has a considerable size of the closed digital market, and a significant budget to invest in collaborative IoT projects. Over the last decade, the EU has developed policy capacities and resources to facilitate the early formation of the IoT industry. The empirical case, therefore, offers a unique opportunity to explore the role of public policy in path creation from the supranational EU level.

This paper is structured as follows. After the introduction, the second section reviews current debates on the role of policies in regional path creation from the field of EEG and innovation studies. The third section looks beyond the region and defines path creation in the EU perspective as to facilitate the movement and formation of key resources among international, national and sub-national levels. Based on that, the author further defines the key resource formation processes and specifies the role of the EU policies for path creation. The fourth part presents and discusses the method and the empirical case. The last section concludes the main findings, policy implications and reflects the limitations of the study.

2. The role of public policies in path creation

Path creation is the emergence of new industrial development, which is a process of mindful deviation and co-creation by heterogeneous actors and networks (Garud and Karnøe, 2001). At the very core stands the proposition that new industry path does not emerge accidentally. It is widely recognised that path creation is non-linear because the emergent contingencies influence the learning processes (Karnøe and Garud, 2012). Thus, knowledge creation has been the centre of the debate. EEG and regional innovation studies (RIS) contribute to understanding the process as evolutionary and place-dependent. The policy implication, therefore, is to formulate policies based on "related variety" (Boschma, 2014) and "Constructing Regional Advantages" (CRA) (Asheim et al., 2011).

EEG's conceptualization on path creation began at the firm level i.e. such process is conditioned by a region's pre-existing industrial structure and firms' technological relatedness (Frenken and Boschma, 2007; Martin, 2010; Neffke et al., 2011). "Evolutionary" highlights the process of diversification, selection and retention, especially with the notion of related variety, i.e. the diversity of industries in a region that are cognitively related (Frenken and Boschma, 2007). In this regards, history matters, i.e. regions are more likely to diversify into technologically related areas. Policy can take the role to foster cross-sectoral connections for new and established actors (Boschma, 2014).

EEG's firm-centric view has been criticised for downplaying the role of non-firm actors such as institutions and public policy that co-evolve with the firm-based organisational routines (Coenen et al., 2016; Strambach, 2010). One strand of the literature responds by applying a regional innovation system (RIS) perspective. It emphasises that the path creation process is "place-dependent." Regions can be differentiated by knowledge bases - scientific analytical, engineering synthetic and artistic symbolic (Asheim et al., 2011), or by different innovation barriers (Tödtling and Trippl, 2005). Furthermore, Martin and Martin (2016) pointed out that regions vary regarding the formal and governance capacities to support industrial path development. Since each region has its unique spatial settings, the path creation process is contingent not only on the related variety of the firms but also differentiated regional settings in its innovation systems (Asheim et al., 2011; Coenen et al., 2016). This view rejects the top-down approach such as "one-size-fits-all" (assuming that Research and Development policy can benefit every region) and "picking-the-winner" (selecting sectors and regions *a priori* as a target for policy-making) planning strategies. The top-down approach would fail as it neglects related variety and the unique embedded spatial settings at a region. The policy implication is to construct regional advantages and facilitate differentiated learning and adaptation by for example regional policy platforms (Cooke, 2007). These concepts were adopted by policy-makers in the EU's innovation policies such as in the CRA and Smart Specialisation programmes (Boschma, 2014).

Empirical studies pointed out that to only look at the precondition of a region, and knowledge creation is not sufficient. Not only the history matters but how actors and networks understand where the future is heading matters too. Steen (2016) studied the emerging of Norwegian offshore wind industry and stressed the role of agency's visions and expectations as a primary genitive mechanism for path creation. Governments can impact the consensus building of the future visions by creating dialogue space (e.g., hybrid forum) for multi-stakeholders to interact with each other (Dusyk, 2011). For path creation, knowledge is not the only resource that is distributed outside of the regional boundary. Karnøe and Garud (2012) followed the formation of the Danish wind turbine cluster and concluded that path creation is through the co-creation of heterogeneous resources such as the international users, supply competencies, and regulation. Since the formation of these resources is not bounded within the region or state, it provides a window to look beyond the region.

3. Looking beyond the region: define path creation in the EU context

A resource-based view of early path creation helps to elucidate the role of governments in aligning and anchoring critical resources in multi-level institutional environments. This view transcends the national border, thus shed lights on inserting the supranational EU dimension. The EU institutions can play a role to facilitate new technological-based industrial path creation through the regulative, financial and normative power, although the capabilities vary in different policy areas.

The resource-based view of early path creation is inspired by the Technology Innovation System perspective, which stresses the institutional alignment process by actors and networks with technological change (Suurs et al., 2010). Instead of setting a territorial boundary, it follows the movement of actors, networks and institutions for technological development (Carlsson and Stankiewicz, 1991). Thus the alignment process involves the movement of resources by actors and networks through extra-regional linkages. Binz et al. (2016) incorporated the role of extra-regional linkages and defined the early path creation as a process of critical resources alignment and anchoring. Anchoring extra-regional resources refer to the interactive process of actors inducing key resources that emerged from other regions of the global technological field. They specified four key resources, i.e. knowledge, markets, finance, and legitimacy and their formation process, i.e., knowledge creation, markets formation, investment mobilisation and technology legitimacy.

Binz et al. (2016)'s framework embraces the role of extra-regional linkages for key resources formation during the regional path creation. However, it is still based on the region. Besides, they did not differentiate the role of governments and institutions from other types of actors and networks during the resources formation process. Further theoretical development is needed to adapt this resource-based view for analysing the role of EU policies for path creation.

What is path creation in the EU context? From a regional point of view, path creation is a process of alignment and anchoring key resources including extra-regional resources into the region. From a supranational EU policy perspective, this is to facilitate the movement and formation of key resources by actors at the international, national and sub-national levels. But this definition does not tell how to facilitate such process. The nest two parts define the key resources formation processes from the EU perspective and specify further the role of EU public policy during the path creation process.

3.1 Defining key resources formation from the EU perspective

The EU has legislative power to influence the legitimacy of new industries. Besides, the Union has an essential role in facilitating the market formation process for new technologies. That is because the single market integration, as a fundamental priority of the EU, can affect the innovation diffusion across countries and industries. The creation of internal market encourages free movement of goods, people, services and capital, and therefore provides a better allocation of resources for productivity (Suriñach et al., 2009). Regarding knowledge creation and financial mobilisation, the Union, for example, has a large budget to invest in collaborative research across Europe and with other partner countries through projects by transnational consortia of industry and academia (Bach et al., 2014). The paper adopts the key resources that were identified by the Binz et al. (2016)'s framework and defined their formation process from the EU perspective.

Knowledge is the first key resource. "Knowledge relationships may cross over regional and national boundaries, as they do over sector boundaries. Network linkages in general, and non-local linkages within distributed knowledge networks, in particular, are often found to be crucial for learning and innovation, to avoid cognitive lock-in" (Asheim et al., 2011:900). Binz et al. (2016) applied this extra-regional perspective on knowledge formation, which emphasises the creation of knowledge, competencies and interactions among actors. Using this broader perspective, the knowledge creation process that can be facilitated by the EU policies is defined as policy activities that create new technological knowledge and related competencies, including the activities to support interactions of actors and networks at the international, national and sub-national levels.

The second one is the markets. New market segments often do not pre-exist and needed to be created for emerging technologies (Dewald and Truffer, 2011). Especially for new technological-based industries, multiple factors such as compelling business models, technological/industrial standards and the size of the potential market are all crucial (Markard and Truffer, 2008). Business models can be developed somewhere other than the place that such technology has been created. Regions can be used as test-bed for new products and services while the actual market can be international (Bergek et al., 2008a; Xu and Ström, 2016); Technology standardisation is a negotiation process between industry, national entities and international associations (Xu, 2012). In the EU context, the market formation is defined as policy activities that reduce the national and industrial barriers for the creation of new market segments.

Financial investment is critical for emerging industries. Despite raising funds from the private sector, public agencies are also direct investors or co-founders of various research programmes and demonstration projects (Bergek et al., 2008b; Negro and Hekkert, 2008). In the EU, investment mobilisation mainly refers to policy activities that invest in collaborative research and innovation projects.

Legitimacy is a socio-political process, which is a matter of social acceptance and compliance with relevant institutions, for resources to be mobilised, for demand to form and for actors to acquire political strength (Bergek et al., 2008b). Thus this process involves interactions with heterogeneous actors and networks in the new technology field, including the interest groups' lobbying activities and institutional entrepreneurship at different geographical scales (Binz et al., 2016). In the EU, technology legitimacy means policy activities that facilitate the acceptance and compliance of new technologies in the EU policy venue and institutional structures.

3.2 Specifying the role of EU public policy during path creation

The EU policy-making process can be divided into two phases: the agenda-setting phase and policy management phase. Agenda-setting is a process of knowledge and technology legitimacy formation. It includes two tasks, i.e., gaining attention and building credibility (Princen, 2011). The same policy issues can be stressed in different angles and aspects (Baumgartner and Jones, 1993). Gaining attention refers to frame the policy issue in the right way and at the right place (policy venue). For the agenda setter, it is vital to convince the policy-makers that the EU has a good reason and the capability to involve in an issue. This is a process of building credibility, which requires organisational capacity building and claiming authorities (Delaney and Leitner, 1997; Princen, 2011). The organisational capacity building is to form policy community, including the alignment within the EU institutions and with the industry, Member States or international actors. Member States can impact by uploading their national interests (Xu, 2016). In the European Parliament, capacity building is often by the formation of intergroup, e.g. the digital agenda during 2014-2019 (Nedergaard and Jensen, 2014). In the Council, this coalition building can be defined as "network capitals" (Naurin and Lindahl, 2007).

A common practice by the Commission to build up European policy communities is through subsidising interest groups (Princen, 2011). These groups afterwards advocate policy issues at the EU level. Often the Commission and interest groups are actively developing networks of experts and stakeholders in the form of "expert groups," "networks" and "forums" (Princen, 2011). These networks of experts from the Member States or interest groups are especially useful when the Commission proposes new policy issues.

Claiming authority means the EU can only deal with policy issues that cannot be equally well stressed by the Member States (the principle of subsidiarity) or at the international venue (Princen, 2011). Often to legitimise a new policy issue, the EU value must be claimed clear. This can be done by linking an issue to existing policies (e.g., internal market) or policy competencies (e.g., to address the fragmentation) within the EU or identifying common ground (e.g., protection of fundamental human rights).

Various actors and networks are taking part of the EU policy management process, often depending on their policy competencies to a particular area, as well as the type of the legislations. Except for the central decision-making institutions, civil service agencies, advisory committees, independent bodies and lobbying groups can involve during the process. It is outside of the scope of this paper to list them. The resources that are mobilised can be knowledge, markets, finance and legitimacy. The case study will reflect such complexity.

Based on a review of the EU policy-making process, the author further specifies the role of EU policies during key resources formation for path creation (with some sample policy actions) in Table 1.

Table 1: Key resource formation for path creation during the EU policy-making process

Key resources formation	Definition	Agenda-Setting phase	Policy Management Phase
Knowledge creation	Policy activities that create new technological knowledge and related competencies, including the activities to support interactions of actors and networks at the international, national and sub-national levels	Framing policy issues; expert groups, forums, and public consultations	Collaborative research and innovation projects; Conferences, and Seminars; Interactions with key stakeholders at different spatial levels
Markets formation	Policy activities that reduce the national and industrial barriers for the creation of new market segments	-	Policy actions that support single market integration; Demonstration or pilot projects; Standardisation and regulation development
Investment mobilisation	Policy activities that invest in collaborative research and innovation projects	-	Implementing collaborative research and innovation projects
Technology legitimacy	Policy activities that facilitate the acceptance and compliance of new technologies in the EU policy venue and institutional structures	Locating a policy venue; policy community building; claiming authority	Institutional entrepreneurship, including the creation of new regulations and the amendment of existing regulations; the creation and growth of interest groups and their lobbying activities

Source: Author's elaboration and adaptation based on Binz et al. (2016) and Princen (2011)

4. Method and case study

4.1 Method

Due to the explorative nature of my research question that is to understand how to use policies to facilitate the path creation of new technology-based industries on the supranational EU level, this paper applies a qualitative case study approach (Silverman, 2013; Yin, 2013). A particular technological field – the IoT, is chosen to serve as the empirical case. The evolution of the EU IoT policy-making provides a unique opportunity to investigate at the supranational EU level how an on-going global technological vision has been received and facilitated. Data was collected in forms of policy documents, project archives and interviews (Eisenhardt, 1989). Total 18 interviews (see Appendix) were conducted during 2012 to 2017. Semi-structured interview questions were designed according to the expertise of the interviewees. Since the EU IoT policy-making is constantly shaping and shaped by the international technology community, the author has participated in two top conferences in the global IoT field - the 2012 International IoT conference and the 2014 IoT Week, to get contacts and gain a more holistic picture.

4.2 The evolution of the EU IoT policy-making

4.2.1 The Agenda-setting Phase under the first Barroso Commission (2005-2009)

During 2007- 2009 the EU anchored the term IoT as an emerging policy area on the EU's agenda with high expectations for economic growth and fundamental concerns about privacy and security. The 2009 action plan of IoT for Europe outlined 14 ambitious actions including IoT governance, monitoring IoT technological developments, funding research and innovation projects, stimulating institutional awareness and international dialogue. Although not all of the actions were successfully executed in the following years, the EU adopted the term "Internet of Things" as a policy area ahead of its most technologically advanced Member States and other countries. The process was described in gaining attention and building credibility.

Gaining attention

A decade ago, when "Internet of Things" first appeared on the EU agenda setting, it was a nascent vision that was linked with Radio Frequency Identification (RFID) technology policy area. On 15 March 2007, the Commission adopted a Communication (COM(2007) 96 final), which concluded that the Commission would continue to monitor the move towards the "Internet of Things" in which RFID would play a significant role. Since the RFID is an established policy issue, the IoT naturally found its policy venue at Information Society and Media that was led by Commissioner Viviane Reding.

"*It usually takes two years for the Commission to adopt a Communication…so we began the work on IoT already in 2005…It happened when I worked at RFID; I was in contact with these people working on the IoT at the International Telecommunications Union (ITU) at the United Nations. That is how I got acquainted with the phrase, and very quickly I became convinced that the future was there.*" (Interview: Santucci, 2017)

One year later the policy frame was expanded to include RFID and the future internet at the same policy venue. During the French Presidency, the 2007 Communication was followed by three EU Presidency conferences on "RFID and the Internet of Things". The Nice conference called together a Ministerial meeting on future networks and the internet. In particular, it discussed policy recommendations of the Commission regarding the IoT. As a result, the Commission adopted a Communication in September, pointing out the rise of the IoT and concluding the need for further policy actions such as public consultation and debate on its architecture and governance model (COM(2008) 594 final). On 27 November 2008, the Council adopted a conclusion, in which the IoT was recognised as a policy issue and welcomed the Commission to adopt a Communication in 2009 with concrete actions to initiate. At this point, the attention of the IoT as a policy area had been built and legitimised as "poised to develop and to give rise to important possibilities for developing new services but that it also represents risks regarding the protection of individual privacy…ensuring the confidentiality, security, privacy and ethical management of the data that will be exchanged on the Internet of Things" (Council Conclusion 16616/08).

Building Credibility

The EU organisational capacities that have been built on technological fields relating to the IoT laid the foundation for credibility building. Within the EU, for example, the unit Networked Enterprise and RFID (D4) was at the Directorate-General Information Society and Media (DG INFSO). Since 2005 D4 had shifted focus to the "Internet of Things" when the global RFID community evolved towards this direction. Since 2005 D4 organised a series of workshops and expert meetings on the RFID regulation and the IoT, which accumulated knowledge and a community of experts in the emerging policy area of IoT (Interview: Santucci, 2017).

The involvement with DGs is based on their policy competencies. DG Enterprise would be involved when the Commission is proposing IoT policies relating to industrial policy (Interview: Herbert, 2014). Besides, many EU agencies and international organisations are highly relevant to their respective expertise. In the area of standardisation, there are the European Committee for Electrotechnical Standardization and the European Committee for Standardization, the European Standardisation Organisations, machine-to-machine workgroup of the European Telecommunications Standards Institute, the Internet Engineering Task Force, International Organization for Standardization and ITU (COM(2009) 278 final). Regarding the ethics and security issues, The European Group on Ethics in Science and New Technologies and the European Union Agency for Network and Information Security are critical think tanks in the issue of IoT ethics and security (Interview: Santucci, 2017).

As for interest groups, supranational clusters are essential vehicles for the Commission to interact with actors and networks from the national and sub-national level, as well as the international players. The existing clusters were adapted to coordinate and support IoT research projects and facilitate cross-cutting dialogues. The Enterprise Interoperability and Digital Ecosystems clusters merged to be the Future Internet Enterprise Systems. The Cluster of European RFID Projects became the Cluster of European Research Projects on the Internet of Things in October 2008, hence formed the IoT European Research Cluster (IERC) in March 2010.

The EU authorities were claimed in three aspects (COM(2009) 278 final). First is to link the IoT policy issue with the current policy areas such as the RFID and future internet. Second is to assert the European value. The European value emphasises the usage of IoT technologies should stimulate economic growth, improve individuals' well-being, address societal challenges and be designed with European core values, i.e. the protection of privacy and personal data. Protection of personal data is listed as the fundamental human rights of the EU (Charter of Rights, art2:8), and thus the third aspect is to align with such common ground.

The international evolvement of the IoT as a policy issue

Although the rise of the IoT is an industry-driven phenomenon, it caught wide attention from policymakers in the world. The US National Intelligence Council recognised the IoT as one of the six Disruptive Civil Technologies with Potential Impacts on US Interests out to 2025 (National Intelligence Council, 2008). Since 2009, IoT has rapidly evolved from disruptive technologies to national competitive strategies among major economic entities across Euro-Asia. Since the autumn of 2009 China has put IoT as one of the seven national emerging strategic industries for sustainable development and rapidly formed up policy-imposed institutions and demonstration zones to accelerate the creation of the IoT industry (Interview: Ye, 2012, Shen, 2012, Chen, 2014, Yan, 2014, Lou, 2014). Japan and South Korea both announced national IoT policy initiatives during the same year, and other Asian countries, for instance, Singapore was working actively on making IoT national strategy (Interview: Lau, 2012). It was at a time that the EU institutions pioneered the debates of the IoT governance (Weber, 2016). Such ambition, however, was diluted by the time-consuming management and bargaining process in the EU's complex policy landscape.

4.2.2 The policy management under the second Barroso Commission (2010-2014)

The IoT policy management went through the first change in its institutional arrangements during the second term of the Barroso Commission. The debate on the IoT governance structure peaked during the first two years but quickly lost its momentum when the Commission concluded not to carry on. Later the focus has shifted to the creation of IoT Innovation Ecosystems (Interview: Friss, 2014).

Revising the policy frame and venue

The Barroso Commission declared the beginning of the EU 2020 Strategy. One of its initiative- A Digital Agenda for Europe (DAE) that was steered by Commissioner Neelie Kroes, became the new policy venue for IoT. The DAE recognised the IoT as a priority (IP/10/581, MEMO/10/199, and MEMO/10/200). Commissioner Kroes called for democratic debate and broad societal consensus about the IoT governance challenges such as the ethical and privacy aspects (SPEECH/10/279). Thus the frame of the IoT policy issue was interpreted as complex technical, social, political phenomena, consisting of six themes: Architecture, Privacy, Data Protection, Security, Governance, Standards, Identification, and Ethics. Hence the EU authorities were stressed in guarding European values.

The organisational capacity building around DAE

To support the Digital Agenda, DG INFSO was replaced by the Directorate General for Communications Networks, Content & Technology (DG CONNECT) from 1 July 2012. The IoT unit D4 was dissolved and replaced by unit E1 with new staff. Besides, a DAE intergroup was formed at the Parliament.

The policy community building was supported by the supranational cluster mechanism "concertation", which allowed the knowledge sharing and consensus building on the interests and visions of the IoT among the members (Interview: Santucci, 2017). For instance, the IERC cluster grouped together the IoT projects under the FP7, as well as national IoT initiatives (Interview: Friss, 2014, Vermesan, 2014). Since 2009, IoT Conference (IoT Week) has been held annually, and in 2013 the IoT Forum was created to promote international dialogue and cooperation on the IoT.

The failures and successes of IoT policy management

The IoT governance issue was pursued by the Commission via setting up expert groups (2010/C 217/08) and public consultations (IP/12/360). The expert groups included 45 European and international members with competence in the areas of legislation, business, and technology. The central question is whether the IoT needs a distinct governance structure (e.g. an intergovernmental IoT treaty organisation in connection with the UN), and the conclusion was no, at least at that stage, the existing multi-stakeholder structures of Internet governance were sufficient (Kleinwächter, 2012). These two conflicting IoT governance approaches represent two major groups of interests in responding to the emergence of the IoT. One group of interests considers the IoT within the Internet sphere, and the others seek for a new order. At the end of 2012, the two groups came to a compromise. That was to continue the IoT research and innovation projects within the current Internet governance structure. The expert group was dismissed, which was a loss of organisational capacity and policy competence.

Since there was no consensus to carry on IoT governance issues, the focus was put on building the IoT innovation ecosystem. This was supported by implementing the collaborative research and innovation projects and the supranational clusters. The EU funding for collaborative IoT research and innovation projects began already in 2009. Projects were often a consortium of partners from several countries, with some having international partners. The implementation of these projects involved groups of experts such as in the programme committees and advisory groups. Those experts were appointed by the Member States to support the Commission. During the FP7 period, an estimate of total € 50-60 million was invested as direct funding for collaborative IoT projects (Interview: Santucci, 2017).

International cooperation was carried out through mechanisms such as joint international calls or bilateral dialogues. For instance, the EU and China, both as early adopters of the IoT in their policy agenda, formed a joint advisory forum since February 2011. Experts from both regions met biannually for political and technical dialogues (Interview: Wang, 2012; Zheng, 2012).

The changing IoT landscape within and outside of the EU

The failed endeavour on launching a comprehensive IoT governance structure has constrained the EU's role as an institutional entrepreneur for the emerging global IoT industry. During the years when the EU was focusing on innovation ecosystem building, the IoT policy initiatives from other countries including the EU's Member States were accelerating. In 2013, The US launched a white house led national IoT project – Smart America Challenge. As regards the IoT governance issue, the US Federal Trade Commission (FTC) did a study on its privacy and security, and suggested a self-regulatory approach, along with enactment of data security and broad-based privacy legislation (FTC, 2015). The Chinese government invested ¥ 1.5 billion in around 500 IoT R&D projects during 2011-2015 (Interview: CIACT A, 2017). By 2015, the estimated size of the Chinese IoT industry reached ¥75 Billion, with the formation of several key IoT industrial clusters and demonstration cities (Interview: CIACT B, 2017). Within the EU, the technologically advanced Member States began to launch national IoT strategies with financial instruments. The United Kingdom (UK) government started IoT UK project since 2014 and by 2015 had committed over £113 million to IoT research. Germany designated €200 million for Industry 4.0 in its national high-tech 2020 plan. France allocated a €50 million fund to connected objects projects (European Parliament Briefing PE 557.012). The IoT is an industry-driven phenomenon. A 2014 IoT patent study showed the competitive landscape was dominated by multinational companies (MNCs) (LexInnova, 2014). Ericsson published an IoT white paper in 2011 and predicted that there would be more than 50 billion connected devices by 2020. This "50 billion" hype quickly went viral among industries and policymakers worldwide, even though the estimation might be too optimistic (Interview: Färjh, 2012). An increasing number of global telecom and tech firms were committed to promoting the IoT industry such as Bosch, CISCO, Microsoft, Google, Amazon, Alibaba and so on (Interview: Miao, 2012). A German IoT firm database indicates that by March 2015, there were at least 317 MNCs running IoT projects (Database: IoT Analytics).

When the EU reframed its IoT policy priority in 2016, the IoT landscape had fundamentally changed - it was no longer an intangible vision but rather a reality. The EU was facing increasing international competition and fragmentation among the Member States and the industries.

4.2.3 The policy management under the Juncker Commission (2014-now)

Second revision of the policy frame and venue

The reframing of the IoT policy issue during the Juncker Commission was driven by the market deployment of the IoT and its economic promise, more than the social, political complexity. A Commission study suggested that the IoT in Europe has already moved from the pioneer phase to widespread adoption, with the potential market value of €976 billion by 2020 (Aguzzi et al., 2014). This revised frame was then incorporated in the digital single market (DSM) policy venue. In May 2015, the Commission launched the DSM strategy, in which the IoT was considered as a technology central to the EU's competitiveness (COM(2015) 192 final). One year later, a Communication from the Commission affirmed such role in digitalizing the European industry (COM(2016) 180 final). The EU authority was claimed to tackle the national and industrial barriers, the lock-in in the ecosystem, a human-centered IoT, and uncertainty in business models and standards (SWD(2016) 110 final).

The organisational capability building around the DSM

Since November 2014, the Juncker Commission set out the DSM as a policy priority. Commissioner Oettinger succeeded Commissioner Kroes in 2014, and since January 2017, the DSM has been steered by vice president Andrus Ansip. In July 2016, DG CONNECT was reorganised to support the DSM strategy. Unit E4 replaced E1 to coordinate and support IoT related policy actions and projects. Other DGs and many units at DG CONNECT are involved according to their competencies. For instance, unit Components (A4) was working together with E1 in coordinating the IoT Focus Area research projects in Horizon 2020 (Riemenschneider, 2015). DG AGRI (Agriculture and Rural Development) is involved for the smart farming IoT pilot implementation and DG SANTE (Health and Food Safety) for the active ageing pilot (Interview: E4, 2017). The project management has been increasingly assigned to executive agencies such as the Innovation and Networks Executive Agency and Executive Agency for Small and Medium-sized Enterprises (Interview: E4, 2017). New clusters evolved with a stronger voice. The Alliance for Internet of Things Innovation (AIOTI) was built from the IERC cluster, aims to develop and support the dialogue and interaction among the IoT actors in Europe. In September 2016, the alliance converted to a Brussels-based European Association, which is a legal entity with goals to become a global influencer in the IoT. IoT European Platform Initiative was created in January 2016 to facilitate the EPI programme in Horizon 2020.

The current IoT policy actions

The IoT policy issues are currently defined in three priorities: 1) A digital single market for the IoT, 2) a thriving IoT ecosystem, and 3) a human-centered IoT (SWD(2016) 110 final). Policy actions are focused on these priorities. There is no direct IoT legislation currently at the EU supranational level, but neighbouring legislations are in process to support the achievement of the single market of the IoT (Interview: E4, 2017). For instance, the reviewing of the EU telecoms rules is related to tackle the interoperability of the IoT systems. The legal and policy actions proposed in the EU data economy initiative (such as the free flow of data, standards, and liability) (COM(2017) 9 final) are highly relevant to the development of a single market of IoT and a human-centered IoT. One key policy action for a thriving IoT ecosystem is the launch of AIOTI in May 2015. The work at AIOTI covers from the IoT ecosystem, policy, standardisation, research and various innovation and industrial application areas.

The IoT research and innovation projects are attracting more investment and expand in terms of funding size and geographical coverage. The IoT has been recognised as a focus area for funding in Horizon 2020. By the end of April 2017, there has been €100 million earmarked to a series of IoT-specific Large Scale Pilots in five areas: Smart living environments for ageing well; Smart Farming and Food Security; Wearables for smart ecosystems; Reference zones in EU cities; and Autonomous vehicles in a connected environment. These areas were selected based on the result of an online public consultation with various stakeholders at different geographical levels[1]. Energy could be the next area to invest in (Interview: E4, 2017). The Large Scale Pilots are designed to bring the innovation of IoT to achieve a critical mass. The previous IoT R&D projects were usually involving 5-7 members, while the LSPs can be as big as having 90 partners (Interview: E4, 2017). These partners are a combination of members from the technologically advanced countries and the more periphery countries, as well as international actors[2]. Another €53 million from Horizon 2020 is for European IoT Platform Initiative. The purpose is to overcome the fragmentation of vertically-oriented closed systems, architectures and application areas. An additional €10 million is allocated for SMEs and start-ups working with these platforms (Interview: E4, 2017). Clusters are continuously used to support and coordinate the IoT research projects.

International cooperation is through policy dialogues and joint calls under Horizon 2020 with strategic partners such as Japan, South Korea, China, Brazil and the US. The trend is to go eastward (Asia) (Interview: E4, 2017). The cooperation serves as an international platform for consensus building of the global IoT policy and standards.

The current IoT policy priorities and activities show that the EU has been increasingly taking the role of a supporter of the industry than as a supranational legislator. One explanation could be that in the race of time, the IoT technology is evolving at a speed that is much faster and the legislative progress. So a softer legislative approach that is less time consuming, e.g. Commission Recommendation (around two years) can be a tentative solution (Interview: Santucci, 2017).

5. Discussion

5.1 Supranational resource concertation

Based on the resource-based view of path creation, "supranational resource concertation" has played an essential role of the EU institutions to facilitate the emergence of the IoT industry. Concertation is defined as a form of dialogue and co-decision among various actors and networks for a unified proposal or concerted action. The EU decision-making is a combination of institutional entrepreneurship and time-consuming bargaining process. Because co-decision is the fundamental principle, resources and decision-making power are distributed among different institutions and between political groups at the EU level. For this reason, resource concertation is the way for the EU to set up new policy issues and implement unified policy actions for new industry formation.

Supranational resource concertation during the agenda-setting phase

This phase involved mainly two types of key resources: knowledge and legitimacy. The policy actions for knowledge creation included framing the policy issue via series of Communications and Council Conclusion during EU workshops and conferences, and supported by expert groups and cluster studies. In the beginning, international contacts with the ITU were a trigger. The policy actions for legitimacy began with the formation of policy venue, through the recognition of EU acts and strengthened by the rise of interest groups such as clusters and forums. The Commission's policy entrepreneurship played an important role to anchor the IoT as an EU policy issue.

Supranational resource concertation during the policy management phase

During the policy management phase until 2017, key policy actions can be divided into three areas: the IoT governance structure, the collaborative IoT research and innovation projects, and international dialogue. In terms of standardisation and regulation, the EU so far has been mainly acting to monitor the development.

The formation and movement of four resources are distributed in all policy actions. During the efforts of launching IoT governance structure, expert groups and public consultation were the major policy actions for knowledge creation and technology legitimacy. If it was successfully propelled, the result would be a supranational or intergovernmental regulation, which would be beneficial for market formation. Although it was suspended, the accumulated knowledge and competencies have been carried by the supranational cluster. When the time is ripe, it is possible that the governance and ethical issue can be pushed forward again.

The collaborative IoT research and innovation projects are related to the formation and movement of all the four resources in a multi-scale network. Since the International dialogue and cooperation were within the EU research and innovation framework, the author combines them together. The major contribution of these research projects is to create technology knowledge, competencies and interactions. The interactions are supported by the supranational clusters. These clusters are the key vehicles to coordinate the research activities and develop interest groups. They act as an interaction space for existing and new actors and networks from different sectors and industries to build consensus and share knowledge. Thus implementing these collaborative projects support the market formation. This has been done by tackling fragmentation through interactions and consensus building among actors, by the result of demonstration projects and large-scale pilots, through monitoring regulation and standard development and in general by building a striving European IoT ecosystem. Investment mobilisation was mainly through the EU funding frameworks (FP7, Horizon 2020). Legitimacy was facilitated by the growth of interest groups and interactions and dialogue with the Member States and industries.

5.2 Policy implications to facilitate the non-linear path of emerging industries

The path for the IoT emergence is non-linear. So does the EU IoT policy-making process. The concepts of related variety and Constructing Regional Advantages were not explicitly mentioned during the IoT policy-making process, but the author found they have been implicitly applied by policy actions. Besides, the case puts forward the importance of the Commission’s policy entrepreneurship and the creation and grows of supranational clusters.

5.2.1 Policy practice applying related variety and CRA

The policy implication of related variety (Boschma, 2014), i.e. fostering cross-cutting connections for new and established actors, was reflected in most of the EU’s policy actions to support the uptake of the IoT industry in Europe, especially by using the cluster mechanism to implement the collaborative research and innovation projects. Consensus building on the vision of the future global IoT industry has been important for the policy-maker to act proactively.

The policy implication of CRA (Asheim et al., 2011) has been seen through the bottom-up resource concertation activities. Often national and sub-national actors from the Member States would group together to apply collaborative research funding which can utilise and strengthen their technological competencies. For example, the application areas for the current Large Scale Pilots were selected through an online public consultation. As a result, the EU institutions avoided picking the sectors. Although in total, the technologically advanced Member States such as Germany, France, Italy, Spain and the UK3 are so far still the top funding receivers, the Commission is trying new funding mechanisms to avoid a further divide between the technologically strong and weak Member States. For instance, the IoT Large Scale Pilots are combining members from the IoT core and periphery countries, as well as introducing international actors together.

5.2.2 The role of the Commission's policy entrepreneurship

The case shows that the Commission's policy entrepreneurship takes a central role to cope with such non-linear challenge. Seemingly, the frequent reshuffle of the Commissioners' policy portfolios and priorities can be harmful to the continuity of policy issues. It is probably true that during the institutional change, there would be a loss of policy capacities (e.g., dismissing of the IoT expert groups). On the other hand, it provides flexibility in at least every five years' term to reframe the policy issue and try an alternative venue. During the last decade, the IoT policy frame and venue has constantly been updated when the Commission set out new policy priorities with new Commissioners. These new frames and new venues are timely linked with the development of the global IoT industry.

The case also indicates that the IoT policy-making did not follow a straight way from agenda setting to policy management. Rather, agendas are often revised during the policy management phase. Organisational capacity and the EU authorities are built and claimed overlappingly with policy management phase.

5.2.3 The role of the supranational clusters

The formation and growth of interest groups are complementary to the Commission's defect on policy continuity. In this case, the rise of various supranational IoT clusters is essential. Clusters are part of this institutional entrepreneurship and vehicle to support related variety. Clusters are main mechanisms for the policy-makers to facilitate cross-national/industry dialogue and concertation with existing and new stakeholders. They are less influenced by the reshuffle at the Commission and the Parliament. If a policy agenda is not executed further at the core EU institutions, the knowledge and capacity can be reserved at the cluster. When a new door is open, such agenda can be raised again. For instance, the IREC (later AIOTI) kept the activities on IoT governance even when the Commission concluded not to continue. Moreover, the cluster can evolve. The AIOTI has transformed to be a legal entity, which largely enhanced its capacity and credibility in promoting the IoT policy issues.

6. Conclusion

This paper concludes that supranational resource concertation describes the key role for EU institutions to facilitate the path creation of the IoT industry. Based on the EU policy-making process, the author developed an analytical framework to discuss the role of EU policies for facilitating the emergence of new technological-based industries. It contributes to the theory development of path creation by inserting a supranational EU dimension. By applying a resource-based view of path creation, the paper defines the EU dimension as to facilitate the creation and movement of key resources by actors at the international, national and sub-national levels. From the case study, the author further identified a chord of policy actions to support supranational resource concertation during different policy-making phases.

Since the path creation process is non-linear, the policy implications contribute to the construction of an evolutionary alternative for policy-makers to tackle this challenge. The EEG and RIS literature proposed to formulate policies based on related variety (Boschma, 2014) and CRA (Asheim et al., 2011). The policy implications of these two concepts are to foster cross-cutting connections for new and established actors and to avoid a top-down approach. These aspects were implicitly reflected in the EU IoT policy practice. Especially in the current IoT Large Scale Pilots projects, a combination of members from the technologically advanced and more periphery countries are grouped together with international actors to reach the critical mass. This is an example of tackling inclusive growth.

The key observation from the IoT case is that as responding to the non-linear emergence of the IoT industry, the policy-making process at the EU level is also non-linear. It is a learning and adaptation process. Policy implications of this observation are twofold. Firstly, policy-makers shall act proactively not based on prediction, but rather on the emerging future direction of the industry. It is based on consensus building among key stakeholders in the technological field. Secondly, future directions and visions of the emerging industry are an evolving thing. Thus mechanisms shall be built to support policy-making as a dynamic resource concertation process. The Commission's policy entrepreneurship that is supported and complemented by the supranational clusters is an example of how to achieve such dynamic balance of various interests.

A major limitation of the study is the lack of supranational regulation. So far, no formal EU IoT law has been approved or implemented. Thus the empirical case is reflecting the policy practice within the framework of intergovernmental cooperation at the EU level. However, when the more controversial side of the IoT is called out during the mass adoption process, not in the form of future possibilities, but in reality, issues such as IoT regulation and ethics will come back to the legislative table. This would be interesting to follow up. Nevertheless, the study shows that the regional foci for new technological-based industry path creation are too narrow. The case reveals that how policies from a supranational level can influence the emergence of the IoT industry in Europe. It is not an aspatial process, but rather, a path creation that embeds the interactions between the supranational level and the Member States, and in the interplay between the industry and various levels of the governments. Key industry players that promote the rise of the IoT can direct lobby their interest on the EU level, or through their national representatives at the EU level. The EU institutions including the supranational clusters facilitate the key resources creation and movement for path creation at the international, national and sub-national levels.

Notes:

1. The result of the online public consultation was published at https://ec.europa.eu/digital-single-market/en/news/public-consultation-internet-things-large-scale-pilots-read-outcome (accessed 15 May 2017)
2. The geographical coverage of members can be found at the Cordis database. For example, the large-scale pilot for Active Ageing and self-management of health is at http://cordis.europa.eu/project/rcn/206761_en.html (accessed 25 May 2017)
3. The conclusion is based on the number of projects that a country received during the FP7 and Horizon 2020. Data source is from Cordis at http://cordis.europa.eu/. Using key words "Internet of Things".

References

Aguzzi S, Bradshaw D, Canning M, Cansfield M, Carter P, Cattaneo G, Gusmeroli S, Micheletti G, Rotondi D and Stevens R (2014) *Definition of a Research and Innovation Policy Leveraging Cloud Computing and IoT Combination-A study prepared for the European Commission DG Communications Networks, Content & Technology*. Report. Luxembourg: Publications Office.

Asheim B, Boschma R and Cooke P (2011) Constructing Regional Advantage: Platform Policies Based on Related Variety and Differentiated Knowledge Bases. *Regional Studies* 45(7): 893–904.

Asheim B and Gertler MS (2005) The Geography of Innovation: Regional Innovation Systems. In: Fagerberg J and Mowery DC (eds), *The Oxford handbook of innovation*, Oxford: Oxford University Press, 291–317.

Asheim B and Isaksen A (2002) Regional Innovation Systems: The Integration of Local 'Sticky' and Global 'Ubiquitous' Knowledge. *The Journal of Technology Transfer* 27(1): 77–86.

Ashton K (2009) That "Internet of Things" Thing: In the real world, things matter more than ideas. *RFID Journal*: 1–2.

Bach L, Matt M and Wolff S (2014) How do firms perceive policy rationales behind the variety of instruments supporting collaborative R& D? Lessons from the European Framework Programs. *Technovation* 34(5–6): 327–337.

Bergek A, Jacobsson S, Carlsson B, Lindmark S, and Rickne A (2008a) Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy* 37(3): 407–429.

Bergek A, Jacobsson S and Sandén BA (2008b) 'Legitimation' and 'development of positive externalities': two key processes in the formation phase of technological innovation systems. *Technology Analysis & Strategic Management* 20(5): 575–592.

Binz C, Truffer B and Coenen L (2016) Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing. *Economic Geography* 92(2): 172–200.

Boschma R (2014) Constructing Regional Advantage and Smart Specialisation: Comparison of Two European Policy Concepts. *Scienze Regionali* 13: 51–68.

Boschma R and Frenken K (2006) Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography* 6(3):273–302.

Boschma R, Frenken K, Bathelt H, Feldman M, and Kogler D (2012) Technological relatedness and regional branching. In: Bathelt H, Feldman M and Kogler D (eds), Beyond territory. *Dynamic geographies of knowledge creation, diffusion and innovation.* London: Routledge, 64-81.

Carlsson B and Stankiewicz R (1991) On the nature, function and composition of technological systems. *Journal of Evolutionary Economics* 1(2): 93–118.

Coenen L, Asheim B, Bugge MM and Herstad SJ (2016) Advancing regional innovation systems: What does evolutionary economic geography bring to the policy table? *Environment and Planning C: Government and Policy* 35 (4): 600-620.

Cooke P (2007) To Construct Regional Advantage from Innovation Systems First Build Policy Platforms. *European Planning Studies* 15(2): 179–194.

Dawley S (2014) Creating New Paths? Offshore Wind, Policy Activism, and Peripheral Region Development. *Economic Geography* 90(1): 91–112.

Delaney D and Leitner H (1997) The political construction of scale. *Political Geography* 16(2): 93–97.

Dewald U and Truffer B (2011) Market Formation in Technological Innovation Systems—Diffusion of Photovoltaic Applications in Germany. *Industry & Innovation* 18(3): 285–300.

Dusyk N (2011) Downstream Effects of a Hybrid Forum: The Case of the Site C Hydroelectric Dam in British Columbia, Canada. *Annals of the Association of American Geographers* 101(4): 873–881.

Eisenhardt KM (1989) Building Theories from Case Research. *The Academy of Management Review* 14(4): 532–550.

Frenken K and Boschma RA (2007) A theoretical framework for evolutionary economic geography: Industrial dynamics and urban growth as a branching process. *Journal of Economic Geography* 7(5): 635–649.

FTC (2015) Internet of Things Privacy & Security in a Connected World. Report of Federal Trade Commission, Washington. D.C.,US, January. Available from: https://www.ftc.gov/system/files/documents/reports/federal-trade-commission-staffreport-november-2013-workshop-entitled-internet-things-privacy/150127iotrpt.pdf (accessed 15 May 2017).

Garud R and Karnøe P (2001) Path Dependence as a Process of Mindful Deviation. In: Garud R. and Karnøe P. (eds), *Path dependence and creation*, Hove, East Sussex: Psychology Press, 1–40.

LexInnova (2014) *Internet of Things: Patent Landscape Analysis*. Report, LexInnova. Available from: http://www.wipo.int/edocs/plrdocs/en/internet_of_things.pdf (accessed 14 April 2017).

IoT Analytics (2015) IoT company database. IoT Analytics GmbH.

Karnøe P and Garud R (2012) Path Creation: Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster. *European Planning Studies* 20(5): 733–752.

Kleinwächter W (2012) *Final Report of the EU IOT Task Force on IOT Governance. Report*, European Commission, Brussels. Available from: http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=7664&no=13 (accessed 15 May 2017).

Markard J and Truffer B (2008) Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy* 37(4): 596–615.

Martin H and Martin Roman (2016) Policy capacities for new regional industrial path development - The case of new media and biogas in southern Sweden. *Environment and Planning C: Government and Policy* 35(3):518-536.

Martin Ron (2010) Roepke Lecture in Economic Geography—Rethinking Regional Path Dependence: Beyond Lock-in to Evolution. *Economic Geography* 86(1): 1–27.

Martin Ron and Sunley P (2006) Path dependence and regional economic evolution. *Journal of Economic Geography* 6(4): 395–437.

National Intelligence Council (2008) *Disruptive Civil Technologies Six Technologies With Potential Impacts on US Interests Out to 2025*. Report, National Intelligence Council, Washington. D.C., US, April. Available from: https://fas.org/irp/nic/disruptive.pdf (accessed 14 May 2017)

Naurin D and Lindahl R (2007) Network Capital and Cooperation Patterns in the Working Groups of the Council of the EU. *CERGU Working Papers Series:* 07.01.

Nedergaard P and Jensen MD (2014) The anatomy of intergroups – network governance in the political engine room of the European Parliament. *Policy Studies* 35(2): 192–209.

Neffke F, Henning M and Boschma R (2011) How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography* 87(3): 237–265.

Negro SO and Hekkert MP (2008) Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. *Technology Analysis & Strategic Management* 20(4): 465–482.

Princen S (2011) Agenda-setting strategies in EU policy processes. *Journal of European Public Policy* 18(7): 927–943.

Riemenschneider R (2015) Presentation of IoT Research and Innovation in Horizon 2020. Available from: http://ec.europa.eu/information_society/newsroom/image/document/2015-51/ec_presentation_on_iot-wearable_call_2016_12765.pdf (accessed 14 April 2017).

Silverman D (2013) *Doing Qualitative Research: A Practical Handbook*. London: SAGE Publications.

Steen M (2016) Reconsidering path creation in economic geography: aspects of agency, temporality and methods. *European Planning Studies* 24(9): 1605–1622.

Strambach S. (2010) Path dependence and path plasticity: the co-evolution of institutions and innovation–the German customized business software industry. In: Boschma R. and Martin R. (eds), *The Handbook of Evolutionary Economic Geography*, Cheltenham and Northampton, MA: Edward Elgar, 406–431.

Suriñach J, Autant-Bernard C, Manca F, Massard N and Moreno R (2009) *The diffusion/adoption of innovation in the Internal Market*. Report. Available from: http://ec.europa.eu/economy_finance/publications/pages/publication15826_en.pdf (accessed 7 May 2017).

Suurs R., Hekkert M., Kieboom S. and Smits R. (2010) Understanding the formative stage of technological innovation system development: The case of natural gas as an automotive fuel. *Energy Policy* 38(1): 419–431.

Tödtling F and Trippl M (2005) One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy* 34(8): 1203–1219.

Tödtling F, Asheim B and Boschma R (2013) Knowledge sourcing, innovation and constructing advantage in regions of Europe. *European Urban and Regional Studies* 20(2): 161–169.

Weber RH (2016) Governance of the Internet of Things—From Infancy to First Attempts of Implementation? *Laws* 5(3): 28.

Xu X (2012) Internet of Things in Service Innovation. *The Amfiteatru Economic Journal* 14(6): 698–720.

Xu X (2016) Interactions between Sweden and the EU before and after the Digital Agenda. In: Linda Berg and Rutger Lindahl (eds), *Förhoppningar och farhågor - Sveriges första 20 år i EU*, Gothenburg: Centre for European Research, 217–232.

Xu X and Ström P (2016) The Transformative Roles of Knowledge-Intensive Business Services in Developing Green ICT: Evidence from Gothenburg, Sweden. In: *Services and the Green Economy*, London: Palgrave Macmillan, 99–124.

Yin R.K. (2013) *Case Study Research: Design and Methods*. 5th Edition. Thousand Oaks, CA: SAGE Publications.

The EU policy documents

TFEU. Consolidated versions of the Treaty on European Union and the Treaty on the Functioning of the European Union 2012/C 326/01.

Charter of Fundamental Rights of the European Union, 26 October 2012, 2012/C 326/02.

COM(2008) 594 final. COMMUNICATION from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Radio Frequency Identification (RFID) in Europe: steps towards a policy framework.

COM(2009) 278 final. COMMUNICATION from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Internet of Things — An action plan for Europe.

COM(2015) 192 final. COMMUNICATION from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A Digital Single Market Strategy for Europe.

COM(2016) 180 final. COMMUNICATION from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Digitising European Industry Reaping the full benefits of a Digital Single Market.

Council Conclusion 16616/08. Council Conclusion to delegations on future networks and the internet, TELECOM 218, COMPET 541, DATAPROTECT 103.

SWD(2016) 110 final. Commission staff working document -Advancing the Internet of Things in Europe.

IP/10/581. Digital Agenda: Commission outlines action plan to boost Europe's prosperity and well-being.

IP/12/360. Digital Agenda: Commission consults on rules for wirelessly connected devices - the "Internet of Things".

MEMO/10/199. Digital Agenda for Europe: what would it do for me?

MEMO/10/200. Digital Agenda for Europe: key initiatives.

SPEECH/10/279. Bringing European values to the Internet of Things. 2nd Annual Internet of Things Conference. Brussels, 1st June 2010.

2010/C 217/08. COMMISSION DECISION of 10 August 2010 setting up the Expert Group on the Internet of Things.

Appendix: Interview list

Name	Role and Organization	Interview date	Types of the organization
Lirong, Zheng	KTH, Stockholm, Sweden & Fudan University, Shanghai, China. Expert of Sino-Europe IoT Expert Group.	2012-Oct-24	Institution/Academia
Tianchun, Ye	Director, China R&D center for IoT	2012-Oct-25	Institution/Academia
Chee-Dai, Lau	The Info-communications Development Authority of Singapore (IDA)	2012-Oct-25	Government
Guangping, Shen	Asisitant General Manager, China Sensor Network International Innovation Park, Wuxi municipal government	2012-Oct-25	Government
Kelvin, Miao	Project Manager at IBM (Smarter Cities)	2012- Oct -26	Industry
Junyu, Wang	Associate Professor, Associate Director, Auto-ID Lab,China, Microelectronics Fudan University, China	2012- Oct -30	Institution/Academia
Jan Färjh	Vice President, Head of Ericsson Research	2012- Oct -26	Industry
Dapeng, Chen	Deputy Director,China R&D center for IoT	2014-Mar-06	Institution
Yuan, Yan	Director Assistant ,China R&D center for IoT	2014- Mar -06	Institution
Zhiqiang, Lou	Beijing Municipal Commission of Economy and Information Technology	2014- Mar -11	Government
Hongbo, Mo	IoT Standards and Patents Center of China R&D center for IoT	2014- Mar -12	Institution
Didier, Herbert	heads the unit for Sustainable Industrial Policy in the DG Enterprises and Industry of the European Commission	2014-May-21	Government
Ovidiu, Vermesan	IERC Cluster Coordinator, Chief Scientist SINTEF, Oslo, Norway	2014-June-27	Institution/Academia
Peter, Friess	IoT Coordinator, DG Connect of the European Commission	2014-June-27	Government
CAICT A	IoT Policy Expert , China Academy of Telecommunication Research of MIIT (CAICT)	2017-Mar-06	Government
CAICT B	IoT Policy Expert , CAICT	2017-Mar-07	Government
E4	IoT Coordinator , Unit IoT, DG Connect of the European Commission	2017-Apr-21	Government
Gerald, Santucci	Former head of unit RFID and IoT, DG Connect of the European Commission	2017-Apr-25	Government