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Dynamic Capabilities in EU Spectrum Management: Assessing the Impact on Single Market Competitiveness in Comparison with the USA

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ABSTRACT

This thesis explores the effectiveness of spectrum management in the EU and the USA through the lenses of Dynamic Capabilities Theory. The research evaluates the EU's ability in sensing, seizing and transforming, which constitute the three core components of the Theory. While the EU has proved strong sensing capabilities in early identifying incoming technological trends, like 5G, through comprehensive strategic initiatives such as the 5G Action Plan, its seizing ability has denoted a structural weakness in policy implementation, hindered by fragmented governance and delays in key phases, such as spectrum auctions.
Contrarily, the USA's centralized, market-driven approach in spectrum management has demonstrated stronger dynamic capabilities, most notably in seizing and transforming. The centralized supervision of the Federal Communications Commission (FCC) has enabled the USA to carry out timely auctions thanks to higher regulatory flexibility, successful public-private partnerships (PPPs) and faster adaptation to innovative models of spectrum use, such as those envisaged in the Citizens Broadband Radio Service (CBRS).
The research adopts a comparative cross-country analysis, with the aim of identifying key similarities and differences in spectrum governance. The resulting findings suggest that while the EU denotes strong capabilities in strategic foresight, it lacks the harmonization of spectrum and the regulatory flexibility necessary to match the pace of technological innovation. Finally, the thesis formulates policy recommendations to enhance EU's dynamic capabilities in seizing and transforming, by advocating for improved harmonization, adoption of spectrum sharing models and strengthening of public-private partnerships
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Chapter 1: Introduction

1.1 Background and Context

The management of radio spectrum is a critical component in determining European Union's (EU) capability to preserve and enhance the competitiveness of the Single Market in the current increasingly dynamic global digital economy.

Radio spectrum is an unvaluable natural resource enabling all forms of wireless communication, such as 5G mobile network, broadcasting, satellites services and newly developing cutting-edge technological applications such as Internet of Things (IoT) and AI (Cave & Webb, 2015).

Over the course of the last decade, the EU has clearly set the ambitious target of becoming a global leader in the digital age, objective of pivotal importance as, according to the (World Economic Forum's (2020) estimates, "*70% of new value created over the coming decade will be based on digitally-enabled platform business models".* The achievement of such ambitious status necessitates the support of an efficient radio spectrum management, essential for ensuring robust connectivity, providing a fertile ground for innovation and enhancing economic growth within the Single Market.

The pivotal role of radio spectrum management is stressed by the EU itself. In its Digital Single Market strategy, project aiming at establishing a fully integrated functioning digital economy across the Union, the Commission has clearly set the achievement of high-quality connectivity as strategic cornerstone (European Commission, 2015). The delivering of high performing connectivity to citizens and businesses would enable the deployment of innovative services and cutting-edge technologies, key elements in the safeguard and support of economic competitiveness.

To improve its spectrum management capabilities, the EU has adopted a set of significant legislation. The European Electronic Communications Code (EECC), also known as the "Code", adopted in 2018, constitutes a critical step in this direction by establishing an increasingly harmonized framework for spectrum management across the EU (European Parliament, 2018). The Code favours efficient allocation and exploitation of the spectrum

natural resource, with notable focus on supporting innovation and deployment of modern digital services.

Nothwistanding considerable achievements, the EU still faces systemic difficulties in safeguarding, and eventually boosting, its competitiveness in the global digital economy. In fact, the Union is currently undergoing a sensibly downsloping trend in competitiveness vis a vis global contender. As according to the World Economic Forum's Global Competitiveness Report (2020), the loss of economic performance is strictly related to deficiencies in innovation capabilities and ICT adoption, all elements intrinsically linked to radio spectrum management. As visually depicted in the European 5G Observatory Map (European 5G Observatory, 2020), the uneven pace of 5G deployment across the continent represents a clear example of weakness in new technological adoption, with Member States lagging behind due to low levels of harmonization and coordination, provoking significant inefficiencies in allocation and assignment processes. As according to the European 5G Observatory Quarterly Report (European 5G Observatory, 2020), in 2020 only a small portion of EU countries had fully assigned the 5G pioneer bands (700 MHz, 3.6 GHz, and 26 GHz), while international competitors like the United States benefited from a considerable head start in this respect, managing to carry out a faster assignment of these bands.

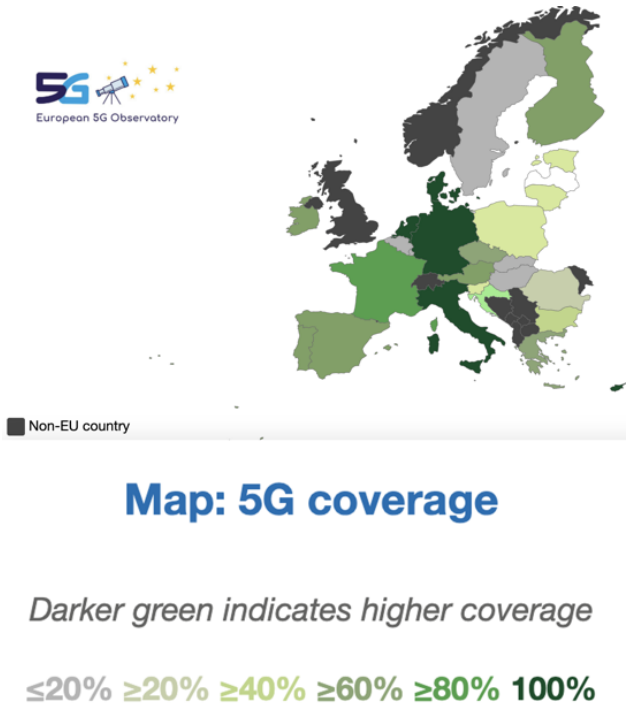

Figure 1 - Map 5G Coverage (European 5G Observatory)

The uneven deployment of cutting-edge technologies however does not solely represent an inter-state issue but also an intra-state one. In fact, the differences in availability and reliability of internet access between urban and rural areas constitute a serious obstacle for the development of innovation capabilities. For instance, as according to the Digital Economy and Society Index (DESI) 2020 report, 85% of households in urban areas had access to fast broadband (at least 30 Mbp) while the digit drops to only 59% in rural areas (European Commission, 2020).

Based on such premises, the key focus of the following research is therefore to assess, relying on the theoretical framework of the Dynamic Capabilities Theory (explained thoroughly in ch.2), whether the EU spectrum management approach is well fit to efficiently address the dynamic and innovative demands of the digital economy. Furthermore, at a later stage, we aim to formulate policy recommendations to enhance the effectiveness of the EU approach, based on findings resulting from the EU-USA cross-national comparison conducted during the study. To make the research more concrete and carefully tailored on our goal, being the "digital" a too broad horizontal concept to be analyzed, we have specifically individuated the realm of connectivity (mainly dealing with 5G) as our main focus.

In doing so, our thesis will attempt to answer the following research question, which will represent our North Star over the course of the research:

- What has been the effect of EU radio spectrum management on the competitiveness of the Single Market through the development of dynamic capabilities?

The results of the analysis will highlight eventual EU weaknesses in radio spectrum management, if any, providing us with a clear overview of the elements preventing the full exploitation of the EU digital economy, consequently influencing negatively the competitiveness of the Single Market as a whole.

1.2EU Single Market: the Core of the EU Political and Economic Project

The European Union's Single Market constitutes the cornerstone of EU's political and economic integration. It has arguably represented, along with the quest for peace and political collaboration, the most attractive feature of the all-encompassing European project started in

the old continent after the second devastating World War. Since the inception of the European Community, the economic ingredient has been persistently present, proof of its primary role in the overall project. Starting from its official foundation in 1993, the Single Market has encapsuled the regulatory framework enabling the free movement of goods, services, capital and people across the borders of the Union, currently covering over 450 million consumers, with a GDP of € 14.5 trillion, accounting for around 14% of the world's trade in goods (second only to China) (Facts and Figures, EU Economy | European Union, n.d.).

Its effects are perceived both externally as well as internally. In 2021, intra-EU trade accounted for 63% of the total EU trade, showcasing its instrumental role as merger of interests among EU countries (Eurostat, 2022). This internal effect could only be possible through an EU-wide shared set of regulatory instruments such as decisions, directive and regulations, all aiming at harmonizing national rules and removing trade barriers to foster cross-border collaboration. In addition, the Single Market provides a fertile ground for competition, efficiency and innovation across sectors by ensuring a level playing field for economic activity. These key elements support the primary role played by the Union in the current, always more competitive, international arena, enabling member states to leverage their individual and collective economic power in international fora's trade negotiations.

Therefore, the undeniably central role played by the Single Market in achieving the EU's political and economic objectives, makes it a critical subject of analysis for any researcher aiming at assessing the status of the EU in specific economic and policy field, in our case in that of radio spectrum management.

In the following thesis, the focus on the Single Market is additionally driven by the interest in assessing the causes behind its current sensible decline in economic competitiveness, element which may have potentially disruptive consequences on the overall resilience of the EU project. The relevance of the topic is widely acknowledged at all levels of the political spectrum. For instance, at the EU level, the Commission has requested Mario Draghi to draft a comprehensive report titled "The Future of European Competitiveness", intended as a cornerstone for the refocusing on competitiveness in the incoming Commission's agenda. Meanwhile, the shift of attention on competitiveness comes also from the national level, with the 27 leaders of the European Union calling for a *'new competitiveness deal'* to close the economic gap with its global rivals and reverse a worrying trend of industrial decline (Euronews, 2024)

1.3 Radio Spectrum: an Invisible but Ubiquitous Natural Resource

The digital economy, as for most of human's productive activities, makes extensive use of natural resources for its proper functioning. Our political-economy enquiry will specifically investigate the policy management of an invisible although ubiquitous natural resource, backbone of the digital economy: the radio spectrum. But, before diving into the policy assessment, the technicality of the subject requires a solid basic knowledge of what is the radio spectrum, and which are the services it enables.

The radio spectrum is a precise category of electromagnetic radiation. It is a finite and invaluable natural resource capable of propagating through solid materials, air and the vacuum of space without the need of support from a physical medium (Massaro, 2017). It comprehends the range of electromagnetic frequencies supporting wireless communication spanning from as low as 3kHz to as high as 300 GHz, with each frequency suitable to support specific types of communication services. Its propagation properties are conventionally defined in terms of wavelength and frequency (inversely proportional between each other's) (NASA, 2013). Among the electromagnetic radiations, the radio spectrum exhibits the longest wavelength making it suitable for long distance transmission, fundamental in communication.

Among the communication services supported by radio spectrum we can find maritime and aeronautical applications (using low frequencies) and cellular networks, Wi-Fi, satellite communications and broadcasting (using high frequencies) (Cave & Webb, 2015). The wide set of applications supported by the radio spectrum makes it a necessary natural resource for economic activity and daily life. For instance, applications such as internet connectivity, mobile telephony, radio and television broadcasting and GPS navigations would not be possible in case of unavailability of radio spectrum.

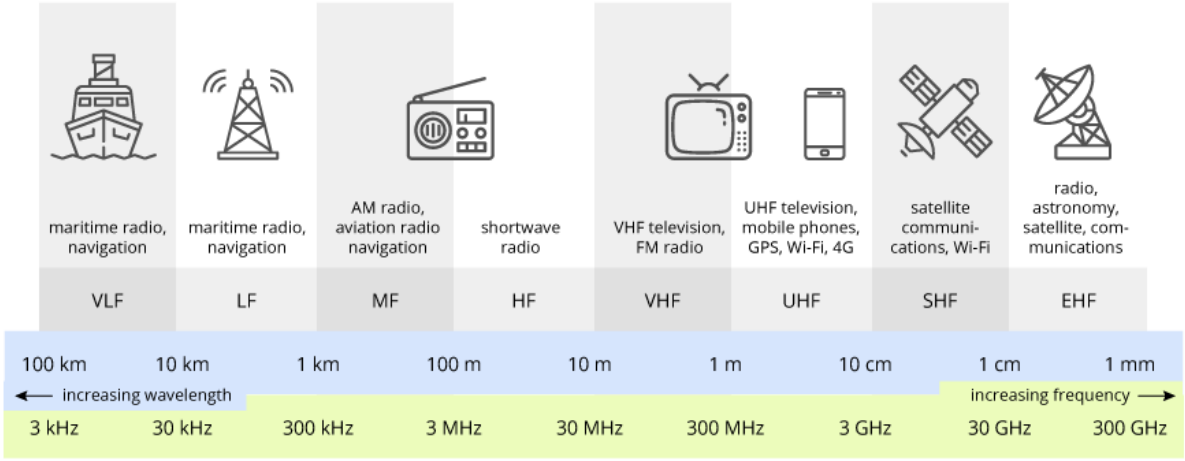

Figure 2 - Radio Spectrum Technological Applications

Over the past recent years, the proliferation of wireless technologies and the Internet of Things (IoT) has resulted in a dramatic expansion in the number of applications based on spectrum, consequently provoking an increased demand. This trend adds to the necessity of an effective governance of this natural resource, critical issue for policymakers. As according to Cisco 2020 annual report, the staggering increment in mobile data traffic, also supported by the emergence of technologies such as 5G networks, would increasingly augment in the years to come, further stressing the imperative for policymakers and regulators to develop an efficient radio spectrum management to reap the benefits of connectivity, fostering innovation and ensuring a sustainable economic growth (Boccardi et al., 2016).

1.4 Spectrum's Allocation and Assignment Procedures

Once fully grasped the basic (rather technical) knowledge underlying what the natural resource of radio spectrum is and why is it relevant for its applications, it is now time to clarify two key concepts related to radio spectrum management: those of Allocation and Assignment. Spectrum allocation and assignment are the two critical components in the overall management of the resource. The interplay between these two procedures largely determines the effectiveness of radio spectrum management, deeply influencing the quality of connectivity and of regional market competitiveness.

Spectrum allocation involves the attribution of specific frequency bands to certain types of services or categories of use, as for example satellite communications, GPS services, mobile

broadband or broadcasting. This process is typically conducted at the global level of governance, with the International Telecommunication Union (ITU) as facilitator of international agreements at the World Radiocommunication Conferences (WRCs). Spectrum allocation principally aims at ensuring a wide harmonization of frequency bands use across borders, preventing interference and supporting the global interoperability of cross-border technology uses. For example, ITU's allocation of the 700MHz band for mobile broadband has critically enhanced the deployment of 4G and 5G networks across the globe (ITU, 2021).

As mentioned, the two procedures are strictly intertwined as, once frequency bands have been allocated, spectrum assignment takes place. This phase involves the concession of specific rights of use of the frequency bands directly to service providers and operators. The process can come under multiple forms based on the regulations in place at the country level. It is often conducted through competitive auctions, where governments have the possibility of earning remarkable revenues; Germany's 2019 5G bands spectrum auctions provide us with a noteworthy example as they have generated €6.5 bilion for the 3.6 GHz alone (European Commission, 2020). As we can expect by now, also the governance of spectrum assignment is critical in supporting economic competitiveness; for instance, a sub-optimal assignment process can prevent market access to smaller operators, leading to reduced competition. An additional issue concerns the temporal length of the assigned licenses, typically long-term and often spanning 15-20 years, feature which could eventually limit the flexibility in adapting to newly emerging technologies and evolved market conditions, constraining the development of innovation capabilities. For such reason, policymakers and regulatory authorities are increasingly exploring new models of spectrum assignment such as that of Licensed Shared Access (LSA), which would permit multiple users to access the band without causing harmful interference. In this regard, the USA's Citizens Broadband Radio Service (CBRS) constitutes a noteworthy example employing a three-tiered dynamic spectrum sharing model across the 3.5GHz band, prioritizing federal users (such as U.S. military and fixed satellite service operators) but still conceding commercial use on a discretional basis (FCC, 2021).

In sum, allocation and assignment procedures are pivotal in spectrum management. The well-execution of these two processes through an efficient governance is key in supporting economic competitiveness and innovation capabilities. However, it requires a strategic and forward-looking approach in policymaking, able to contemporarily balance a multiplicity of interests ~~attemoting~~attempting to extract the maximum benefit from the radio spectrum.

1.5 International, European and EU Radio Spectrum Governance

Now that we acquired the technical knowledge of the resource and understood the two key elements shaping its governance process, the next step of our introductory section deals with a comprehensive overview of the key players and procedures present at the multiple levels of radio spectrum governance.

Policymakers and regulatory authorities play a key role in spectrum management. This natural resource, although ultimately under national sovereignty, is managed through a complex multilayered governance framework aiming at balancing global coordination and regional needs.

At the global level, the International Telecommunication Union (ITU), a specialized United Nations' agency, takes the lead in international governance. The ITU's Radio Regulations, discussed and established every four years at the World Radiocommunication Conference (WRC), wish to coordinate and harmonize the radio spectrum governance globally by allocating specific frequencies to a limited number of types of services. This harmonization, among other things, aims at preventing harmful interference which, as according to art. 1003's definition of the ITU Constitution, is an "*interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations* (ITU, 2021), meanwhile supporting an effective functioning of the regional layer of spectrum governance.

Speaking of regional level, the ITU envisages 6 regional divisions to ensure a carefully tailored approach based on the specific needs of the area under scope. The regions are: Africa region (ITU-AFR), Americas Region (ITU-AMR), Arab States Region (ITU-ARB), Asia-Pacific Region (ITU-ASP), Commonwealth of independent States Region (ITU-CIS) and the region under the scrutiny of our research, the Europe Region (ITU-EUR).

In the European region, the governance of radio spectrum is coordinated at the EU level where the Commission and the Radio Spectrum Policy Group (RSPG) (*a high-level advisory group that assists the European Commission in the development of radio spectrum policy*) collaborate

to ensure optimal level of coordination and harmonization of spectrum governance across the Union, promoting the establishment of a fully functioning Single Digital Market (Radio Spectrum Policy Group, 2021). European Union's legislation contributes to such overreaching goal. The European Electronic Communications Code (EECC) provides a common legal framework for the lawful management of spectrum policy across the Union, improving competition, driving innovation, encouraging the efficient use of the resource and securing consumer rights within the European Single Market (European Parliament, 2018). A harmonized and coordinated management of spectrum bands across the EU Single Market is a necessary condition for enabling the deployment of pan-European services like that of 5G, key in safeguarding competitiveness and promoting innovation capabilities all over the Union.

Traditionally, natural resources are under sovereignty and unconstrained management of the state in which they are geographically located. However, in the case of the EU this fragmented approach has caused major inefficiencies overtime, making cross-border frequency coordination very challenging and hindering a coordinated deployment of new cutting-edge technologies (Falch & Henten, 2010). For these reasons, the EU spectrum management has significantly evolved over time, slowly moving from an exclusively nationally-focused approach toward an increasingly EU-focused management, ultimately becoming subject of shared competence (Cave & Webb, 2015).

Once acknowledged the competitive disadvantages caused by such imperfect approach, the EU has taken significant steps further in increasingly sustain harmonization and coordination aiming at developing a common regulatory framework in spectrum management. Notable landmarks in this process include the establishment in 1988 of the European Telecommunications Standards Institute (ETSI), a European Standards Organization (ESO) supporting European regulations and legislation through the creation of Harmonised European Standards; the formation of the already mentioned Radio Spectrum Policy Group (RSPG) in 2002; the radio spectrum decision (2002/676/EC) in 2002, establishing a policy and legal framework for strategic planning and harmonization, and the European Electronic Communications Code (EECC) (Directive (EU) 2018/1972) in 2018, comprehensively covering EU telecommunications rules, including updated regulations on radio spectrum management.

In short, spectrum management is a globally complex multilayered interplay of stakeholders attempting to coordinate and cooperate to reap the maximum benefits from an efficient use of

this resource. For what concerns the region under our scrutiny, namely the European region, the supranational body of the EU plays a central role in policy management at the regional level, supporting harmonization and coordination among member states to promote the establishment of a truly Single Digital Market.

1.6 Research Problem, Objectives and Practical Implications

Having acquired a more comprehensive understanding of the topic at stake, along with the relevant elements involved in radio spectrum management, we can now address the ultimate goal of our research.

The research problem centers around the evaluation of the effectiveness of the EU's radio spectrum policy management in safeguarding and eventually enhancing the competitiveness of the Single Market. More specifically, our work aims at scrutinizing whether the EU's approach in radio spectrum management is successful in supporting the deployment of advanced digital technologies, fostering innovation and ultimately ensuring the EU with the economic competitiveness necessary to play a primary role in the digital economy at the global level. This assessment is particularly relevant at this precise moment in time when new revolutionary technologies such as 5G, IoT and artificial intelligence (AI) are being increasingly deployed, all of which systematically depend on the availability and efficient management of radio spectrum.

Our assessment will be conducted within the theoretical framework of the Dynamic Capabilities Theory developed by Teece, Pisano, and Shuen (1997). The theory provides a meaningful analytical instrument to test the capabilities of a subject, in our case a supranational organization as the EU, in sensing opportunities and threats, seizing those opportunities and threats into strategic actions and transforming its internal resources to accommodate the newly altered conditions (Teece, 2007). This theory fits well in our research as its application was originally conceived to test a subject's dynamic capabilities in the context of rapidly changing and innovation-based environments, clearly akin to our radio spectrum and digital economy case-study.

Specifically, we apply this analytical framework to assess whether the EU spectrum management satisfies the dynamic capabilities' needs of the three key stages: sensing, seizing and transforming. In summary, we will be detecting whether the EU effectively manages to:

1. Sense technological trends, market demands, and regulatory challenges related to the management of spectrum and its technological applications such as, but not limited to, 5G, IoT and AI.
2. Seize emerging opportunities through carefully tailored strategic actions in spectrum management, as for instance in auctions, allocation and assignment procedures.
3. Transform its regulatory framework to remain competitive in the continuously evolving digital sector. In this case, flexibility is the key element necessary for shaping new methods and approaches, learning from past experience.

Once applied the Dynamic Capabilities Theory's analytical framework and identified the (eventual) weaknesses in the EU approach, we will conduct a cross-national comparison with the USA's spectrum management approach. Such theoretical exercise will initially provide us an overview of the different approaches between the two subjects and, consequently, we will attempt to individuate areas of improvements for the EU based on USA's comparative findings. Elements such as dynamic spectrum sharing, regulatory innovation and rapid deployment of new technologies will constitute integral elements of our assessment.

Finally, based on findings resulting from the Dynamic Capabilities Theory's evaluation and the EU-USA's cross-national comparison, we will attempt to formulate actionable policy recommendations apt to enhance the effectiveness of EU's radio spectrum management in support of the competitiveness of the Single Market.

This thesis has the ambition of empirically contributing to the application of Dynamic Capabilities Theory in policy analysis by furnishing practical implications to policymakers and industry stakeholder dealing with radio spectrum management and its applications. The following assessment will attempt to give rise to insightful policy ideas and practical evaluations, underlining the centrality of a forward-looking and adaptable strategic policy approach in dealing with fast-paced technological innovation.

1.7 Research Question(s)

The complexity of the subject under evaluation requires a clear research question driving our assessment. As previously cited in paragraph 1.1, the research question is the following:

- What has been the effect of EU radio spectrum management on the competitiveness of the Single Market through the development of dynamic capabilities?

The research question will guide our assessment making sure that it will not steer too far from the core objective. However, due to the complexity of the issue at stake, our research will likely touch upon multiple sub-topics, always related to the practice of radio spectrum management. Among them we could find specific results related to sensing, seizing and transforming capabilities, and valuable comparative findings on the differences in approach between the EU and USA, particularly in areas where the EU may be lacking effectiveness.

1.8 Thesis Structure

Chapter 1 had the goal of providing a comprehensive outline of the research topic and research objectives, meanwhile introducing the reader to the notions necessary to fully comprehend the subject under scrutiny. The following chapters are purposely designed to ordinately tackle the issues necessary to coherently answer the research question and its previously stated objectives.

The thesis is structured as follows:

- Chapter 2 – Theoretical Framework:
    - This chapter outlines in detail the theoretical framework supporting the research, with a primary focus on the exegesis of the Dynamic Capabilities Theory. In addition, this section further details the concepts of radio spectrum management, connectivity and competitiveness along with their related issues and trends, all pivotal elements of the research. The comprehensive overview provided in this chapter finalizes the reader's preparation before diving into the concrete analysis.

- Chapter 3 – Research Methodology:
    - This chapter provides a full overview of the research design, data collection methods and set of techniques adopted in the work, as for instance the guidelines

in governing the interviews with experts of the sector. It explains the rationale underlining the research in the areas of sensing, seizing and transforming and the relevance of the comparative methodology adopted. Finally, it outlines ethical considerations and eventual limitations structurally inherent to the research.

- Chapter 4: Analysis and Findings
    - This chapter outlines the empirical analysis and findings resulting from the research. It carries out the core assessment by addressing EU radio spectrum management's sensing, seizing and transforming capabilities testing them on the blueprint of the Dynamic Capabilities Theory. The findings resulting from the analysis will lay the ground for the following chapter of cross-national comparison and the final discussion.

- Chapter 5: EU-USA Comparative Analysis
    - This chapter contains the cross-national EU-USA comparative analysis of radio spectrum management approaches. Firstly, this section aims at highlighting the respective differences (extensively focusing on areas where the EU can learn from USA's best practices) and, secondly at formulating policy recommendations for improving the EU's dynamic capabilities in radio spectrum management.

- Chapter 6: Conclusions
    - This chapter constitutes the last step of the research by summarizing the key findings and policy recommendations, discussing their significance in enhancing the EU's spectrum management and competitiveness. It provides a final overview of the research and outlines final remarks underlining the importance of adaptive governance of radio spectrum and the broader implications of the findings for the future of the EU Single Market.

1.9 Conclusion

This first introductory chapter has provided us with a bird's-eye view of the topics, objectives, challenges and structure of the thesis. It has evidenced the critical role of radio spectrum

management in the EU's digital strategy as well as its fundamental impact on the overall competitiveness of the Single Market. Moreover, it has provided us with a first understanding (more in depth in chapter 2) of the theoretical framework of the Dynamic Capabilities Theory, analytical backbone of the overall assessment. Finally, it has provided a clear definition of the research question and research objectives, also outlining a roadmap for the following analysis, beginning from the theoretical framework covered in chapter 2.

Chapter 2: Theoretical Framework

2.1 Chapter Overview

Chapter 2 lays the foundations of our research by presenting the theoretical framework onto which this thesis is built on, particular attention is dedicated to the application of the Dynamic Capabilities Theory, central element of our analysis. In addition, this section outlines trends and factors central to our inquiry. Among the key topics detailed in this chapter we can find: Dynamic Capabilities Theory, EU Radio spectrum governance, connectivity and competitiveness of the Single Market, and EU-USA cross-national comparative studies. Finally, by identifying potential gaps in the literature, it attempts to underline the originality of the research which could potentially constitute a contribution to academic and policy studies.

2.2 Theoretical Framework: Dynamic Capabilities Theory

Dynamic Capabilities Theory is a theory developed by David J. Teece, Gary Pisano and Amy Shuen which constitutes a foundational work in strategic management, providing an insightful theoretical structure to assess how organizations can thrive in environments characterized by dynamicity, fast-paced innovation and technological disruption. The origins of the theory trace back to 1980s and 1990s, when scholars started to notice the limitations of conventional theories' assuming relative staticity of the environment, evidently in contrast with the market's increased dynamicity favoured by technological innovation (Nelson & Winter, 1982; Wernerfelt, 1984). The shortening in length of technological cycles made phenomena of technological disruption more common, demanding organizations to develop new dynamic capabilities to cope with the evolved landscape on a regular basis.

In this context, Teece, Pisano, and Shuen (1997) developed the concept of dynamic capabilities, defined as "*the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments*.", underlining the pivotal role played by components such as adaptation, flexibility and strategic reconfiguration of firms' resources in the safeguard of competitiveness.

The theory developed in contrast to the widely recognized Resource-Based View (RBV) which emphasizes the role played by static aspects, sustaining that firm's competitiveness is

essentially dependent on the possession and deployment of valuable, rare and inimitable resources (Barney, 1991). In sharp contraposition, the Dynamic Capabilities Theory principally focuses on the processes (rather than the static resources) through which organizations predict, adjust and remodel their resources to face challenges, seize new opportunities and eventually enhance their competitiveness (Teece, Pisano, & Shuen, 1997).

More specifically, Dynamic Capabilities Theory sustains that adaptability and flexibility constitute the primary characteristics for an organization to achieve long-term competitiveness in a continuously transforming environment where external changes often imply new challenges. This adaptability is enclosed in three interconnected processes named as "sensing", "seizing" and "transforming". These three components enable the organization to sense and predict new opportunities and threats, implement newly conceived strategies to capitalize on them and reconfigure its existing resources to efficiently carry out the actions necessary for remaining competitive over time (Teece, 2007).

Overtime, the theory has been revisited by numerous scholars which have tried to tailor its application to more specific contexts. However, the three core concepts outlined in the initial theory, namely sensing, seizing and transforming, remained overall unchanged. For the sake of our assessment, we argue that the theory could find an application not only within the corporate context, but also in that of public governance, enabling us to understand the role of supranational entities, in our case the EU, in maintaining competitiveness.

In sum, Dynamic Capabilities Theory furnishes us with a well-defined framework for assessing the effectiveness of public institutions' adaptability and flexibility in face of new challenges, aiming at reaching their public policies' objectives (Ambrosini & Bowman, 2009). In the context of our research, the role of the three core elements of the theory (sensing, seizing and transforming) remains unchanged and its application will enable us to infer whether or not the EU demonstrates dynamic capabilities in radio spectrum management for the sake of fostering connectivity, innovation and economic growth.

2.3 Core Components: Sensing, Seizing, and Transforming

A detailed comprehension of the elements involved in sensing, seizing and transforming processes (both as conceptualized in the original theory and as declined in our case study) is a

necessary step before carrying out the assessment. These three core components are intrinsically linked with each other's as the effectiveness of each of them has clear implications on that of the remaining two. Therefore, the final overall assessment of the organization's dynamic capabilities depends on the well-execution and coherent development of each one of the three phases.

The three components are the following:

- Sensing: it refers to the organization's ability to predict, identify and evaluate threats and opportunities arising in the environment. In a highly dynamic context, this process demands efficacy in early detecting technological trends to sense the possibility of new technological disruptions of markets, in predicting potential shifts in regulatory trends and customer's preferences. Sensing capabilities equip the organization with the ability to promptly respond to changing conditions, necessary starting point for a successful seizing process.

  Specifically to our case study, sensing capabilities in the EU's radio spectrum management entail the ability to forecast spectrum demand based on the deployment of new cutting-edge technologies (5G, IoT and AI being clear examples) and changing customer preferences (Teece, 2007). A successful EU sensing process heavily relies on the exploitation of both internal and external resources. The effective leverage of existing internal EU resources, such as data collection and forecasts formulation, enables the institution to tackle proactively, instead of reactively, incoming threats and challenges. On the other hand, external resources' exploitation heavily relies on active engagement of external actors such as industry stakeholders, industry experts, academic researchers, policymakers and consumers in identifying the incoming trends. The Radio Spectrum Policy Group (RSPG) constitutes a critical component in this phase, furnishing an optimal forum for industry stakeholders and states to participate in the EU spectrum governance through consultations, working groups and regular meetings. This approach provides the EU with the diversity of perspectives and expertise necessary to gain a valuable foresight of what could be potential incoming challenges and threats impacting on radio spectrum governance. All these elements contribute to empowering the EU with the necessary resources to develop dynamic capabilities during the sensing process. (Danneels, 2011). As a practical example, the EU "sensing" of the strategic relevance of 5G connectivity has led to the implementation of the 5G

Action Plan, setting the path for the "seizing" and "transforming" stages which resulted in the deployment of 5G networks across Member States (European Commission, 2016).

- Seizing: it refers to the strategic utilization of resources and capabilities to face the threats and opportunities individuated during the sensing phase. This process demands the ability to plan and execute strategic actions in allocating resources, investments and setting organizational priorities. Similarly to the sensing process, also seizing places adaptability and flexibility at the centre of dynamic capabilities' development. In fact, along with strategic planning and execution, the success of the seizing process depends on the ability of the subject to overcome organizational inertia and adopt new operational processes to extract the maximum from emerging opportunities.
  In the context of the EU, seizing capabilities are mirrored in the capacity of designing and implementing strategic spectrum policies, carrying out timely auctions, fostering public-private partnership to empower digital infrastructures and support the innovation necessary to deploy next-generation networks (Teece, 2007). As according to European Parliament, (2018) the EU has undertaken significant efforts in this direction, aiming at harmonizing and coordinating timely national spectrum auctions to ensure availability of spectrum bands for 5G deployment. This represents a clear example, although not always successful, of dynamic capabilities development during the seizing process.

- Transforming: it refers to the continuous reshaping of capabilities and resources to meet the evolving demands and external conditions. This process focuses on renewing organization's assets and competences while also abandoning outdated practices. Once again, also transforming capabilities require a notable level of adaptability and flexibility to let the organization be responsive and agile in a dynamic environment (Teece, 2007).
  In the context of the EU, transforming capabilities refer to the institutional responsiveness and ability in updating regulatory frameworks and organizational structures, adjusting strategic objectives and reallocating resources based on newly evolved technological trends and market demands. Specifically in radio spectrum governance, transforming capabilities entail the ability of adjusting spectrum allocation

policies for accommodating the deployment of new strategic technologies, implementing innovative methods of spectrum use (such as spectrum-sharing models) and ensuring a fertile ground for innovation (Helfat et al., 2007). Effective transforming capabilities in radio spectrum management enable the EU to reap the maximum benefits from the deployment of new cutting-edge technologies, key in promoting competitiveness across the Single Market. The Radio Spectrum Policy Programme (RSPP), an EU project aimed at ensuring transforming capabilities in the field of spectrum management, constitutes a clear example of best-practice in this phase. The Commission leads this programme, specifically under the supervision of DG CONNECT, to promote efforts in implementing spectrum sharing and dynamic spectrum access, new models of spectrum use which, among other things, provide enhanced flexibility, key element in transforming capabilities.

In summary, Dynamic Capabilities Theory will constitute the foundational analytical framework in our assessment of the EU spectrum management practices. The focus on the three core components, will provide us with the comprehensive view necessary for evaluating the EU's spectrum management strengths and weaknesses in managing threats and challenges of the digital age. The findings resulting from the assessment will then constitute the basis for the formulation of policy recommendations aimed at favouring dynamic capabilities development in support of Single Market competitiveness.

2.4 Historical Evolution of Radio Spectrum Management in the EU

Now that we have a thorough understanding of what Dynamic Capabilities Theory is and its application in our study, we can proceed in untangling another core element of our research, namely the practice of radio spectrum management in the EU.

Radio spectrum management is a pivotal component of the EU's digital strategy, deeply influencing, connectivity, competitiveness and economic growth across the Single Market. Being a finite source, radio spectrum requires an effective allocation and assignment management for fully extracting its maximum benefits in support of strategic sectors such as telecommunications, satellite services and broadcasting.

The historical evolution of spectrum management in the EU reflects a similar pattern to that of telecommunications policies. At the origin, both telecommunications as well as spectrum

management were governed at the national level, with almost unrestricted sovereignty in the hands of Member States and a relatively low level of cross-border coordination. However, as the liberalization of telecommunication markets advanced in the 1990s driven by EU directives, spectrum management evolved accordingly. The advancement of regulations favouring competition in previously monopolized sectors, provoked increased harmonization of spectrum policies across states to ensure the necessary level playing field across the Single Market (Falch & Henten, 2000).

The institution of the Radio Spectrum Policy Group (RSPG) in 2002 represented a landmark in the EU's approach to spectrum management. As according to European Commission (2002), the RSPG was established to provide a forum for coordination among Members States in spectrum management practices, facilitating a common framework for allocation and usage. Almost contemporarily during 2002, the adoption of the Radio Spectrum Decision (676/2002/EC) strengthened the efforts toward an increasingly coordinated approach by establishing harmonization procedures across Member States to support the deployment of cross-border services and improve the efficiency of frequency bands use. Afterward, on December 1, 2019, the Lisbon Treaty entered into force enlarging EU competences over areas such as telecommunications and spectrum policy thanks to the expanded scope of the internal market. From then onwards, spectrum management has become a shared competence under the enlarged EU competence in regulating the internal market deriving from Article 114 TFEU, which also included telecommunications.

The acquired shared competence nature of radio spectrum management, although never explicitly defined but implicitly derived from EU treaties, decisions and legislative acts, strengthened the EU's role in coordinating, harmonizing and guiding national spectrum strategies to ensuring the efficient functioning of the Single Market, nevertheless recognizing a certain level of national sovereignty to Member States.

The latest milestone in the evolution of spectrum management in the EU framework has been marked by the adoption of the European Electronic Communications Code (EECC) in 2018. The EECC established an all-encompassing framework of action for electronic communications across the EU by consolidating and updating previous directives and regulations (European Parliament, 2018). It contributed in setting out rules for spectrum allocation, licensing and included a renovated emphasis on recognition of radio spectrum as shared competence as underlined in Recital 98 of the EECC: "*Given that radio spectrum*

management in the Union is closely linked to the objectives of ensuring the functioning of the internal market, as well as of ensuring the availability of and access to high-quality fixed and mobile electronic communications services throughout the Union, the Union should adopt measures aimed at coordinating the strategic planning, harmonisation and efficient use of radio spectrum.". In addition, it reiterated the pivotal objective of harmonization of management and usage as according to art. Article 45 - General objectives and principles for radio spectrum management: " *Member States shall cooperate with each other and with the Commission in the strategic planning, coordination and harmonisation of the use of radio spectrum in the Union In this respect, they shall take into consideration, inter alia, the economic, safety, health, public interest, freedom of expression, cultural, scientific, social and technical aspects of Union policies, as well as the various interests of radio spectrum user communities with a view to optimising the use of radio spectrum and avoiding harmful interference."*

In sum, the EECC constitutes a pivotal evolution in EU radio spectrum management, reiterating the shared-competence nature of radio spectrum management and stressing once again the necessity for cross-border coordination and harmonization to avoid harmful interference and achieve the broader objectives of the Single Market, such as supporting the EU's 5G Action Plan in 5G network deployment.

2.5 Current EU Regulatory Framework

The current regulatory framework governing EU radio spectrum management is product of the historical evolution of spectrum management practices and legislation culminated with the implementation of the overreaching EECC, up to the point that we could now argue that the current regulatory framework is largely defined by the EECC which sets out allocation, licensing and usage rules across the Single Market. Despite the EECC sets multiple ambitious targets, such as ensuring maximization of spectrum's economic and social values and fostering competition and innovation, its primary goal remains that of spectrum harmonization, essential for the deployment of new technologies such as 5G. However, as according to European Commission (2020), harmonization has proved to be difficult, with delays in spectrum auctions, regulatory fragmentation and incompatibility in policy goals between Member States, hindering the achievement of a cross-European orchestrated action.

To ensure a consistent application of the EU regulatory framework for electronic communications (the EECC being its last landmark) and to provide a formal structure of cooperation among National Regulatory Authorities (NRAs), Regulation (EC) No 1211/2009 instituted the Body of European Regulators for Electronic Communications (BEREC). BEREC's role was later strengthened by means of Regulation (EU) 2018/1971, (part of the EECC) which enlarged its responsibilities and updated its governance structure. Nowadays, BEREC plays a crucial role in overseeing the implementation of the EECC and ensuring consistency across Member States. This Body provides common guidance in spectrum management, oversees compliance and furnishes a forum for exchanging best practices between NRAs.

2.6 Challenges in EU Spectrum Management

Despite considerable efforts undertaken through means of legislation and regulatory activity, the EU still faces challenges in achieving the desired level of harmonization in spectrum management across states. The following list intends to provide the reader with an overview on the key flaws potentially hindering EU spectrum harmonization during sensing, seizing and transforming. The early understanding of issues like regulatory fragmentation, growing spectrum demand and spectrum-political goals alignment, will enable the reader to flawlessly immerge into the upcoming analysis without the need of additional contextualization.

- Regulatory fragmentation: arguably the most critical obstacle, it directly results from differing national implementation of EU directives based on diverging interpretations and different approaches. Fragmentation has often resulted in significant delays in spectrum auctions, uncoordinated availability of frequency bands and uneven speed of deployment of new technologies across Member States, such as with 5G network (European 5G Observatory, 2020).

- Growing spectrum demand: the proliferation of new interconnected devices, the rapid expansion of the IoT and the increment in availability of wireless services pose a significant challenge to spectrum availability and management. As according to Cisco's Annual Internet Report (2020), by 2023 the number of connected devices reached 29bln. This marked a significant increment If compared to 2018, when the count of the devices stopped at 18.4bln, growth predominantly composed of Machine-to-Machine

(M2M) types of connections (around 50%), driven by the adoption of IoT technologies. In this context, the EU's ability in developing dynamic capabilities is critical in securing the necessary availability of spectrum to accommodate the deployment of strategic services and technologies, avoiding the risk of interference. Being spectrum a finite resource, its growing demand naturally leads to spectrum scarcity as long-term challenge, generating potential congestion of frequency bands and eventual conflicts between services and users. To address these potential issues, the EU has taken steps in supporting spectrum-sharing models and facilitating the adoption of technologies using more efficiently spectrum resources (Cave & Webb, 2015).

- Spectrum-political goals alignment: The EU also faces the more politically-fashioned challenge of aligning spectrum management strategies with broader policy goals such as the provision of efficient digital public services, the promotion of digital inclusion and the reduction of digital divide. As according to the European Court of Auditors (2020), spectrum policy management should include strategies in its design to address the above mentioned disparities, permitting all the European citizens to benefit from secure and reliable digital technologies.

The former list, although not covering in detail all the possible flaws, provides us with the overview on the challenges which we will encounter during our research, while assessing EU's Dynamic Capabilities.

2.7 Defining Connectivity and Its Importance

Although ultimately aiming at assessing EU radio spectrum management, our research is deeply linked to the field of connectivity. Given the structural interrelation between radio spectrum and connectivity, insights on the status of regional connectivity provide us with concrete proofs on the effectiveness of EU radio spectrum management. Radio spectrum is in fact the backbone of digital connectivity. The deployment of next generation networks (ex. 5G and wireless services) is intrinsically dependent on the availability of frequency bands which, as we have seen, is one of the key challenges in spectrum management.

In practical terms, connectivity refers to the availability and quality of digital infrastructures such as wireless services, mobile and broadband networks. Having at disposal high-performing connectivity constitutes a necessary step in the achievement of a fully-functioning Digital

Single Market, central element in providing a fertile ground for business innovation, cross-borders scaling and services (including critical sectors such as healthcare and public administration) (European Commission, 2020).

Connectivity plays a crucial role in the modern digital economy. It unleashes the untapped potential of information and communication technologies, permitting the cross-border services necessary for the functioning of the Single Market. A good quality of connectivity constitutes nowadays a prerequisite for driving economic growth, fostering innovation and enhancing productivity, overall permitting the economy to remain competitive vis a vis foreign players. In Europe specifically, the Commission has posed the quest for an effective connectivity as core pillar of its Digital Single Market Strategy, ultimately aiming at establishing a merged marketplace across the EU (European Commission, 2015).

Connectivity is central for innovation across sectors. It provides the necessary platform for the deployment of new cutting-edge strategic technologies such as the Internet of Things (IoT), 5g and Artificial Intelligence (AI). These innovative technologies fundamentally rely on robust and secure communication networks to fully unleash their untapped potential (Manyika et al., 2019). For this reason, connectivity constitutes a necessary enabler of innovation ecosystems, permitting knowledge sharing, cross-border collaboration and support for new technological instruments.

Connectivity constitutes a relevant element in our research also due to its direct link with economic competitiveness. In fact, it is itself a fundamental enabler of competitiveness in the digital economy, favouring economic growth, innovation and being instrumental to broader EU policy goals as for example social inclusion.

In the context of the Single Market, effective EU spectrum management is essential for ensuring that connectivity infrastructures satisfy the demand of the digital market, consequently contributing supporting the economic competitiveness of the EU (García-Murillo & MacInnes, 2020). The European Commission's Digital Economy and Society Index (DESI) constitutes a noteworthy resource in our research, providing a comprehensive assessment of the status of connectivity across the EU region. Indicators such as broadband coverage, internet speeds, and the adoption of digital technologies are instrumental in concretely picturing the current status of EU connectivity.

2.8 Defining Competitiveness and its Key Components

Competitiveness constitutes one of the key elements of our assessment, as we argue that it is strongly influenced by the EU dynamic capabilities in managing radio spectrum. However, we need first to understand more clearly what competitiveness is and how it could be linked to our research.

In the context of the EU Single Market, the term competitiveness refers to the aptness of the EU's regulatory frameworks, institutions, and digital infrastructure in forming an environment favourable for economic productivity, technological innovation and growth for business and industries. This concept is directly linked to the governance of radio spectrum, as an effective spectrum management is conducive to the deployment of advanced infrastructures and technologies like 5G, favouring the EU positioning in the global digital economy.

Among the key components of competitiveness, we can find:

- Regulatory frameworks and institutional bodies: Solid institutions and effective governance models are essential elements in fostering competitiveness. In our research, EU regulatory bodies such as BEREC (Body of European Regulators for Electronic Communications) and RSPG (Radio Spectrum Policy Group) are central players in facilitating competitiveness by supporting increased harmonization across Member States, optimization in allocation and assignment procedures, reduction of spectrum auctions timelines and fastened deployment of innovative technologies and digital infrastructure, all elements key for competitiveness (WEF, Global Competitiveness Report).

- Availability of modern digital infrastructures: European Commission’s Digital Economy and Society Index (DESI) underlines the key role of modern digital infrastructures in determining competitiveness. Radio spectrum management heavily influences the availability of modern digital infrastructures, key in supporting the deployment and application of digital technologies sustaining businesses innovation, transformation and improvement of productivity. In fact, always according to DESI Report, Member States enjoying advanced digital infrastructures witness higher levels of economic growth and innovation.

- Innovation capabilities and adoption rate of modern technologies: Innovation capabilities, as also according to Dynamic Capabilities Theory, are a necessary component for an organization to remain competitive. In the EU context, effective spectrum management provides a fertile ground for technological innovation, specifically in newly emerging fields such as that of Internet of Things (IoT) and AI.

The competitiveness of the Single Market is strictly dependent on the availability of digital infrastructure. As global competition intensifies, the aptness of the EU in attracting investments, supporting innovation and keeping economic growth alive in the digital sector is key in safeguarding the EU global economic status. However, critical studies such as the World Economic Forum's Global Competitiveness Report (2022) shed a light on the struggle of the EU in these key areas, revealing a declining EU trend in competitiveness ranking, most notably in the fields related to digital infrastructures, ICT adoption and innovation capabilities, all strictly dependent on connectivity and spectrum management. The lack of improvements in these areas negatively affect EU's global economic power, risking of falling consistently behind major players such as the USA and China in the global race for digital economic competitiveness.

As initially clarified in the introductory chapter, the outcome of our analysis would provide elements to infer the potential correlation between spectrum management and the downsloping trend in competitiveness that the EU Single Market is undergoing.

2.9 A Systemic Downsloping Trend in Competitiveness of the EU Single Market

The systemic downsloping trend taking place across the EU Single Market is consequence of a series of systemic factors, all interconnected, ranging from regulatory fragmentation and uneven disposal of digital infrastructures across countries, to lack of innovation capabilities and deployment of new technologies. These challenges are reported in economic indicators, research studies and public reports stressing the need for swift reforms to revert the trend and provide the Single Market with the necessary tools to economically compete at the global level.

Among the primary elements affecting the declining trend in Single Market's economic competitiveness we can find:

- Regulatory fragmentation and cross-border barriers: The persistence of fragmentation in the regulatory frameworks governing spectrum management across EU countries constitutes one impellent obstacle, perhaps the most impellent, contributing to the decline in competitiveness. This regulatory hurdle is particularly evident in digital markets and telecommunications as the nature of these sectors' services is inherently cross-national. Despite the EU's pledge for a unified economic space in the digital sector (see Digital Single Market strategy), Member States often sustain differing regulations and strategies in key practices such as spectrum management. This fragmentation inhibits the potential benefits of cross-border operations, preventing the efficient functioning of the Single Market, particularly by raising barrier for cross-border trade and investment. The critical necessity of addressing such flaw has been widely recognized also at the supranational level as, according to the European Economic and Social Committee (2019) opinion "*In 2019, fragmentation was costing the EU EUR 990 billion. Doing away with 50% of the obstacles to the free circulation of services would add EUR 279 billion per year to our collective GDP, while an 80% reduction would generate an extra EUR 457 billion. As for the circulation of goods, dismantling the outstanding hurdles would bring the bloc between EUR 228 and 372 billion a year. The digital single market, if fully integrated, would contribute EUR 415 billion per year to the EU economy and create hundreds of thousands of new jobs, while a full transition to e-procurement could generate between EUR 50 and 75 billion a year."* In addition to this, the persistent adoption of new digital regulation without a unified strategy has contributed to the slow deployment of the Digital Single Market, inhibiting EU-based unicorns' scaling and innovation capabilities. As according to the EU Commission's 2023 State of the Digital Decade: *"differences with other advanced economies remain: at the start of 2023 there were 249 unicorns based in the EU, compared to 1,444 in the US and 330 in China"* (European Commission, 2023).

- Declining trend in Global Competitiveness Rankings: The consistent decline in global competitiveness rankings showcases this systemic downsloping trend. As according to the World Economic Forum's Global Competitiveness Report (2022), multiple EU

Member States stagnated or even declined in the rankings. Two leading EU economies such as Germany and France, accounting respectively for 24.2% and 16.6% of total EU GDP, clearly demonstrate the ongoing negative trend. Once consistently in the top 5, Germany has fallen back to 10th position with also France out of the top 20. The EU economic decline in competitiveness ranking reflects a weakening of EU's international position. In the global arena, EU performance is outpaced by major economic competitors such as China and the USA, both well ahead in digital adoption across sectors (World Economic Forum, 2022). For instance, by 2019, only 66% of manufacturing firms in the EU have adopted at least one digital technology, compared to 78% in the US (European Investment Bank, 2019).

- Cross-countries disparities in digital infrastructures and connectivity levels: Disparities in digital infrastructures and connectivity level constitute an additional hurdle hampering Single Market competitiveness across Member States. Although Member States such as Denmark and Sweden enjoy advanced digital infrastructures and optimal levels of connectivity, their achievements are not reflected across all the EU region, with countries lagging far behind. According to the European Commission's Digital Economy and Society Index (DESI) 2021, only 64% of rural households enjoy high-quality connectivity with access to high-speed broadband, figure in sharp contrast with urban areas, where it reaches up to 90% (European Commission, 2021). The disparities in digital infrastructures and connectivity levels negatively affect regional inequalities, consequently weakening the strength of EU political cohesion.

- Expert's opinions on declining competitiveness' trends: A multiplicity of academics and experts of the sector have extensively voiced concerns about the EU capabilities in maintaining the necessary level of competitiveness at the global level. Among them, Mariana Mazzuccato, Professor in the Economics of Innovation and Public Value at University College London where she is the founding director of the UCL Institute for Innovation and Public Purpose, has raised critiques on the EU approach, too often relying on austerity and fiscal prudence, hindering the innovation-led growth necessary to maintain high level of long-term competitiveness. She advocates for a renewed paradigm of public intervention in support of heavy strategic investments in digital infrastructures and of policies fostering innovation. Both necessary requisites to not fall behind in the global competitive race (Mazzucato, 2021). The Italian University

College London Professor is not alone in his critique. Similarly, Dr. Guntram Wolff, Director of Bruegel, a Brussels-based think tank, and Professor of Public Policy and Economics at the Willy Brandt School of Public Policy, has underlined the necessity of an EU harmonized regulatory framework in developing cohesive industrial policies. This achievement would permit the EU to reap the benefits of a cohesive Digital Single Market, delivering on its promises of increased competitiveness (Wolff, 2021).

- Lack of innovation capabilities and productivity levels: Innovation constitutes a foundational pillar of economic competitiveness. Despite being home to top-level research institutions and considerable public R&D investments, the EU struggles in keeping up with the USA and China in converting research into concrete commercial products and services. As according to the European Innovation Scoreboard 2022, EU's innovation performance is improving, yet at a lower rate if compared with its competitors, especially in areas such as digital innovation, AI deployment and biotech (European Commission, 2022). Along with innovation, productivity constitutes a pillar in EU Single Market competitiveness. Productivity growth in the EU has been weak, with labour productivity increasing at a significantly lower pace if compared to the USA. In fact, over the course of the past decade, labour productivity in Europe has increased annually by only 0,8%, with the USA almost doubling the EU pace with a 1,5% annual growth (OECD, 2021). The lack of investments in digital technologies and the slow evolution of Industry 4.0 innovations have significantly contributed to the stagnation of EU productivity, contributing to the declining trend in competitiveness.

2.10 Cross-National Comparative Studies: EU vs. USA

At a later stage, our research will draw from (and potentially contribute to) the field of comparative cross-national studies, specifically those referring to the USA-EU contraposition. Our research will lead to insights highlighting differences in spectrum management approach and eventual contrasting outcomes on connectivity and competitiveness levels.

The EU and the USA adopt significantly diverging approaches in spectrum management. Coherently with its institutional governance, the EU puts emphasis on coordination and harmonization's efforts, while the USA adopts a principally market-based approach ensuring

flexibility in licensing and dynamic spectrum access through frequent auctions. The Federal Communications Commission (FCC) supervises the process, focusing on promoting competition, innovation and investments in digital infrastructures (FCC, 2020).

2.11 Limited Application of Dynamic Capabilities Theory to Spectrum Management

While Dynamic Capabilities theory has been widely applied to firm's strategic management studies, the application to supranational institutions (the EU in our case) and public policy management (radio spectrum management in our case) proves to be rather limited. In order to conduct a meaningful application in such specific fields, this thesis requires the reader to adopt a flexible and open-minded approach in the application of theory. Although perfectly fitting in our context characterized by fast innovation, the application to supranational bodies and public policies does not perfectly match the original contextualization of David J. Teece, Gary Pisano and Amy Shuen.

2.12 Conclusion

This chapter has provided a comprehensive overview of the theoretical framework, trends and factors relevant to our research.

With the application of Dynamic Capabilities Theory to the field of EU's radio spectrum management, this thesis wishes to contribute to the wider understanding of public institution's aptness in developing and maintaining competitiveness in dynamic and technologically driven environments. This chapter has offered a clear understanding of the critical role played by spectrum management in supporting EU connectivity and competitiveness' goals, meanwhile detailing the opportunities and threats faced during the process.

The EU-USA comparative study aims at providing concrete lessons for improving EU's spectrum management, specifically where the application of Dynamic Capabilities Theory evidence weaknesses in the EU approach.

The following chapter 3 will outline the research methodology implemented in addressing the research, outlining fundamental components such as its design, data collection methods and comparative framework, all elements contributing to the soundness of the analysis.

Chapter 3: Research Methodology

3.1 Introduction

This chapter outlines the research methodology implemented while projecting and writing this thesis, from the start to its final version. The research methodology is a key element in the process as it set the guidelines and direction during our investigation on the effectiveness of EU radio spectrum management. As extensively covered in chapter 2, the study applies the theoretical framework of Dynamic Capabilities Theory, testing the efficacy of EU's sensing, seizing and transforming capabilities. In addition, an EU-USA cross-country comparative study enables us to instrumentally analyze the differences in approach between the two subjects and extrapolate policy recommendations based on best practices, most notably in areas denoting EU weaknesses.

This chapter aims at providing a comprehensive overview of the rules followed in the research design, analytical strategies, data collection methods and cross-country comparison while addressing the research question.

3.2 Research Design

The research design is based on a mix-methods approach, where both quantitative and qualitative data are exploited to conduct the comprehensive assessment. We believe the combination of qualitative and quantitative elements to be the best approach in supporting research of complex studies such as those dealing with policy analysis. This mixed-methods approach provides us with qualitative expert's perspectives and quantitative data sources both at the same time, permitting our analysis to tackle specific issue areas from multiple perspectives (Creswell & Plano Clark, 2011).

Specifically to our case, the mixed-methods approach is instrumental in contemporarily conducting an assessment of both public policy frameworks, mainly related to spectrum management, as well as empirical data on connectivity and competitiveness.

3.3 Qualitative Analysis, Quantitative Analysis and Data Collection

The qualitative component of our research primarily deals with the analysis of policy-documents, academic literature, experts' opinions, regulatory frameworks and reports in the field of spectrum management, connectivity and competitiveness. The qualitative analysis centers around recurring trends and themes related to EU spectrum management, providing us with the macro-elements necessary for assessment and comparison. Among the sources scrutinized, key documents include EU-led projects and legislations such as the European Electronic Communications Code (EECC), the 5G Action Plan, the Radio Spectrum Policy Programme (RSPP), and reports from the Body of European Regulators for Electronic Communications (BEREC). In addition, our research is supported by the literature and studies on Dynamic Capabilities Theory and spectrum management. Moreover, the qualitative assessment incorporates findings, commentaries and insights collected by means of separate interviews to three experts in radio spectrum policies, contributing with the industry perspective on the matter. The first and second experts (from now on exp.1 and exp.2) pertain to the private corporate sector, being exp.1 specialized in the European context and exp.2 specialized in the US context. The third expert (from now on exp.3) represents a private organization (not a company) active in the EU context. These interviews enrich the assessment with an insider-vision on the key challenges and opportunities related to spectrum management, permitting to delineate a more nuanced picture of the sector. For the sake of privacy and to facilitate candid unfiltered responses we have opted to keep the interviewees anonymous. This method will also support an unconstrained analysis of the comments and opinions collected during the interviews.

The quantitative component of our research is mainly composed, but not solely, by data collected in the fields of connectivity and competitiveness related to EU radio spectrum management. The quantitative analysis present in our research will enable us to assess the level of dynamic capabilities based on empirical evidence. More specifically, data sources such as the European 5G Observatory, the World Economic Forum's Global Competitiveness Report, the Digital Economy and Society Index (DESI) and industry reports will be key elements in our assessment, providing key metrics such as those on 5G deployment, digital infrastructure investments and broadband coverage. Quantitative data are critical when conducting a comparative study, as they provide common unit of measurement and clear benchmarks

necessary in assessing differing contexts (EU-USA in our case), thereby complementing qualitative findings (Bryman, 2016).

In sum, the adoption of a mixed-methods approach aims at strengthening the accuracy and reliability of our research's findings by relying both on qualitative as well as empirical elements, offering a multi-angle perspective on the issue at stake.

Data collection includes both primary and secondary sources. As for the case of mixed-methods approach, the decision of making extensive use of both primary and secondary data sources aims at providing a more nuanced vision and an extensive set of reliable elements for answering the research question (Flick, 2018).

Primary data collection comprehends semi-structured interviews with exp.1, exp.2 and exp.3. These interviews are designed to gather insights into EU's spectrum management practices, EU's challenges in policy implementation, and EU's dynamic capabilities effectiveness in responding to technological and market changes. The semi-structured design of the interviews enables us to gather insights on predetermined primary topics, but also to allow flexibility in exploring with the desired level of freedom subtopics potentially relevant to our assessment (Kvale & Brinkmann, 2009). The interview questions revolve around the core components of Dynamic Capabilities Theory - sensing, seizing, and transforming. For instance, interviewees are systematically asked about the EU's ability to anticipate future spectrum needs (sensing), its effectiveness in the spectrum assignment process to support 5G deployment (seizing), and its capacity to adapt its practices and regulatory frameworks to emerging technologies (transforming).

Secondary data collection comprehends the gathering and analysis of data contained in policy documents, public reports, academic literature and existing freely accessible datasets. These sources are necessary for providing empirical evidence complementing the qualitative analysis supporting the study. Among the key sources of secondary data consulted during our research we find:

- Digital Economy and Society Index (DESI): mainly for data related to connectivity, digital skills and digital public services across the EU.

- European 5G Observatory: mainly for data related to the 5G rollout progress and spectrum auctions.

- World Economic Forum's Global Competitiveness Report: mainly for data related to global competitiveness, specifically in the digital economy.

- European Commission Legislation and Reports: key documents are represented by the European Electronic Communications Code (EECC) and the 5G Action Plan.

3.4 Analytical Framework

As extensively covered in chapter 2, the analytical framework of our assessment pivots around Dynamic Capabilities theory's three core components: sensing, seizing and transforming. Each component is analyzed to assess whether the EU possesses or not the necessary dynamic capabilities to effectively carry out spectrum management and consequently to infer its influence on connectivity and competitiveness of the Single Market.

3.5 Sensing Capabilities

The assessment of sensing capabilities relies both on qualitative and quantitative data, principally deriving from interviews and policy files. In this case, the insights from the experts will be of great value particularly in the evaluation of the EU's ability in integrating inputs from industry stakeholders.

Key questions guiding our research include:
- How effectively does the EU predict future technological trends and adapts its spectrum needs accordingly?

- What are the mechanisms employed by the EU to collect and scrutinize information about technological and market trends?

- In which ways does the EU integrate stakeholder's inputs into its strategic policy formulation?

3.6 Seizing Capabilities

The assessment of seizing capabilities relies both on qualitative and quantitative data, principally deriving from empirical findings related to spectrum auctions, infrastructure investments and interviewees' judgements on policy outcomes. In this case, the insights from

the experts will be of great value particularly in the evaluation of the ability of the EU in aligning spectrum policies with industry needs.

Key questions guiding our research include:
- How effective are the EU's spectrum allocation practices in supporting connectivity, specifically 5G deployment?

- To what extent do the EU's spectrum policies align with broader economic and social objectives?

- Which are the mechanisms through which the EU fosters public-private collaboration to enhance connectivity?

3.7 Transforming Capabilities

The assessment of transforming capabilities relies both on qualitative and quantitative data, principally deriving from policy files, interviews' findings and studies focused on regulatory adaptation. In this case, the expert's interviews will be of great value particularly in the evaluation of the EU's ability to transform its regulatory approach in response to emerging technological and market trends. The insights collected from both the USA and EU experts will equip our assessment with a comprehensive vision on specific case studies and best practices of the two areas under comparison.

Key questions guiding our research include:
- To what extent are EU's spectrum policies flexible and adaptable to emerging technological trends and market demands?

- What are the EU's mechanisms implemented to revise and update its regulatory frameworks?

- To what extent is the EU effective in fostering innovation in spectrum management?

3.8 Comparative Analysis: EU vs. USA

An additional key element in the thesis is represented by the EU-USA cross-country comparative analysis concerning spectrum management practices.

Comparative research has been extensively applied to individuate best policy practices in differing governance frameworks and, consequently, in highlight potential weaknesses and strengths of approaches (Rose, 2005).

By adopting a distinct approach in spectrum management characterized by market-driven policies, the USA provides us with a meaningful benchmark of comparison to identify best practices which could improve eventual flaws in EU's spectrum management. The comparison will focus on how regulatory flexibility, technological deployment and innovation contribute to the achievement of spectrum management policy goals. The regional expertise of the interviewees further strengthens the validity of the analysis, furnishing insights based directly on stakeholder's experience.

3.9 Ethical Considerations

This thesis adopts a research methodology which follows ethical guidelines and considerations to ensure fairness in the collection and deployment of information, this includes a proper treatment of data stemming from primary and secondary sources.

Quantitative data and qualitative findings (including those collected during interviews) are integral components of the research. We attempt to make use of those data as much according to their original meaning and purpose as possible, avoiding to the maximum extent radical changes in the context of their utilization.

Interviews are conducted according to the same logic. The interviewees are perfectly aware of the purpose and use of the findings stemming from the interviews. We have obtained informed consent from participants, ensuring at the same time anonymity and confidentiality of the interviews content. As previously mentioned, the decision to safeguard anonymity of the interviewees aims at encouraging candid and honest dialogues, avoiding potential professional repercussions based on their answers. This method permits to gain the maximum number of insights, also making us able to utilize the content of the interviews without constrains.

Moreover, the research follows the ordinary procedure to respect source's intellectual property rights by scrupulously citing according to the APA style all references to avoid any sort of plagiarism (Guillemin & Gillam, 2004).

3.10 Limitations of the Research

Despite the extensive attempts in ensuring a well-structured, comprehensive and unbiased assessment of the EU spectrum management, the research methodology still faces structural limitations which must be acknowledged before proceeding with the core analysis.

These include:
- Availability of Data: the extent of the availability of data on spectrum management, connectivity and competitiveness may varies across regions and sources, potentially hindering the comprehensiveness of the analysis. This could for instance negatively affect the reliability of the EU-USA cross-country comparison.

- Subjective Bias in Qualitative Interpretation: the collection and interpretation of qualitative sources may undercome the influence of the researcher's pre-existing bias and beliefs, particularly relevant in the case of interviews' findings. To limit such risk, we have collected data from multiple reliable sources, enriching the perspectives onto which the research is based on.

- Imperfect Comparability: the differences in regulatory framework, technological adoption, market structures, institutional bodies and policy objectives may hinder the soundness of the cross-country EU-USA comparison. Our comparative analysis must take into consideration pre-existing differences which could eventually influence the outcomes of the regional comparison (Rose, 2005).

3.11 Chapter 3 in summary

This chapter has provided the overview of the research methodology implemented in assessing the effectiveness of the EU radio spectrum management in fostering competitiveness and connectivity. The approach is characterized by the exploitation of both qualitative and quantitative data applied in the analytical framework of Dynamic Capabilities Theory. The study aims at providing a comprehensive assessment of the EU's sensing, seizing and transforming capabilities. In addition, expert's interviews and a cross-national EU-US

comparison provide valuable insights on challenges and best practices of the two respective regions, offering valid elements of analysis for policymakers.

The research design, its analytical framework and data collection methods fit coherently with the study structure and purpose, ensuring a clear and rigorous research methods to address the research question.

The following chapter 4 will delve into the core analysis and findings, respecting the guidelines set by the research methodology of this chapter.

Chapter 4: Dynamic Capabilities in EU Spectrum Management

4.1 The Analytical Framework: A Look through the Lenses of Dynamic Capabilities

The following chapter dives into the concrete application of the sensing, seizing and transforming components of the Dynamic Capabilities Theory in relation to the practice of EU radio spectrum management. The lenses of Dynamic Capabilities will permit us to assess the effectiveness of the EU's approach in supporting competitiveness and digital connectivity in each of the three phases.

Our research has helped us to identify a limited number of specific challenges and opportunities which we believe to be critical in determining the EU's capability in spectrum management. This chapter will consistently rely on past examples in management of critical technologies such as 5G, IoT and AI to frame the study into a more concrete dimension. Moreover, expert's interviews will be of capital importance in our evaluation as, along with quantitative data mainly drawn from reports and entities like the Digital Economy and Society Index (DESI) and the European 5G Observatory, will ensure the availability of well-founded qualitative elements based on the interviewees' direct involvement in the sector. All these elements together helped us in precisely identifying the topical areas creating challenges and opportunities in the EU spectrum management.

Dynamic Capability	**Sub-Components**	**Description**
Sensing	- Technological Trend Identification - Market Demand Analysis - Regulatory and Competitive Landscape Monitoring	Capability in identifying technological trends, anticipating shifts in market demands and monitoring internal regulatory framework and external competitive landscape.
Seizing	- Spectrum Assignment Strategies - Regulatory Framework Implementation - Public-Private Collaboration	Capability in translating opportunities in concrete strategic actions making use of the insights gained through sensing. This entails components such as spectrum allocation, implementation of

		regulatory frameworks, and public-private partnerships for investments.
Transforming	- Regulatory Adaptation and Flexibility - Organizational Learning	Capability to adapt and reconfigure the regulatory framework, policy direction and resources according to changing conditions. It entails components such as stakeholder engagement and organizational learning.

Table 1 – Summary of Dynamic Capabilities Subcomponents

4.2 Sensing Capabilities in EU Spectrum Management

Sensing capabilities in EU spectrum management are strongly correlated with the ability of identifying in advance technological trends, predicting the evolution of market demands and monitoring the regulatory and competitive landscape.

4.3 Technological Trend Identification

The capability in early identifying emerging technological trends, represents our first element of analysis, being it a constitutive component of the sensing phase. In newly emerging technologies based on the availability of wireless communication infrastructures, as for instance in 5G, IoT and AI, the early detection of their spectrum demands is critical in favouring a rapid and effective deployment. The EU capability in predicting and planning strategies to accommodate technological innovation is pivotal in determining the competitiveness of the Single Market in the global digital economy.

To concretely assess the effectiveness of the EU approach, we start by referencing to the sensing phase related to 5G, technology nowadays widely recognized as vital. In this area, the EU has early launched in 2016 the 5G Action Plan, a proactive program setting up a comprehensive strategic plan to rapidly ensure a wide deployment of 5G across the Single Market. The project set the ambitious target of guaranteeing full commercial availability of 5G by 2020 and a complete deployment by 2025 in all Member States. The achievement of such targets would have represented a fundamental step for competing at the global level by, among other things, ensuring a potential of €225 billion in worldwide 5G revenues for mobile operator by 2025 (Commission, 2016). This plan, not only set concrete targets, but proactively raised

awareness on the pivotal role of 5G technology which serves as backbone of connectivity for multiple other digital services across industries, spanning from manufacturing to healthcare, from public services to automotive. The 5G Action Plan has been widely recognized by sector experts as highly valuable and strategically well defined. For instance, according to Deutschland spricht über 5G" (literal translation: "*Germany talks about 5G"*), a major forum of discussion in Germany which includes various public and private stakeholders examining implementation, challenges, and future of 5G technology: *"experts are also expecting positive effects on employment, creating around 2 million new jobs within the EU. It all depends on the successful implementation of the EU's so-called 5G Action Plan".* The findings of our research consistently reflect the expert's positive assessment of the EU sensing capabilities.

However, while the EU has proved to be highly successful in sensing the incoming emergence of 5G by proactively shaping a forward-looking comprehensive strategy, the implementing phase has not managed to fully exploit the optimal premises created through sensing. .

Data reports such as that conducted by the the European 5G Observatory Report (2023) furnish us with a more in-depth picture of the flaws in deployment. Despite the ambitious pledges, only 66% of the EU population had at its disposal 5G services by mid-2023, also showcasing significant regional disparities with countries such as Germany, Italy and France achieving fast deployment thanks to substantial policy harmonization and rapid completion of spectrum auctions (European 5G Observatory, 2023). However, this has not proved to be the case for most EU countries which experienced delays, mainly due to national regulatory and political fragility. These mixed-results in deployment rates clearly showcase a weak capability in seizing by turning plans into actions (later addressed in details in paragraphs 4.7, 4.8, 4.9, 4.10, 4.11), markedly evident when compared to other major global players like the USA and China which achieved more rapid and homogeneous deployment rates thanks to, among other things, a market-driven approach and a centralized regulatory framework (FCC, 2023).

During the interviews, both exp.1 and exp.3 stressed the EU efficacy in proactively designing a strategy for the incoming 5G technology, sign of a well-functioning sensing phase. However, this notable capability in sensing did not manage to preemptively tackle market deficiencies and regulatory bottlenecks. Exp.1 distinctively underlined the difficulty in ensuring timely auctions. An early availability of spectrum bands is a necessary element for companies to take

advantage of cross-border services, increasing potential revenues and making the Single Market more attractive for investments. As according to exp.1, the delays in availability of spectrum were principally caused by unnecessary red taping in auctions' procedures, which could have been avoided through better coordination among member states.

As the sensing activity needs to constantly adapt to technological trends and innovation, its assessment represents a continuous theoretical activity which permits us not only to assess past application (as for the case of 5G so far analyzed), but also to observe the current ongoing EU sensing of emerging technologies such as 6G and IoT. Although only at a premature stage, these technologies are expected to revolutionize business activities across the Single Market by providing unmatched reliability, low-latency communications and supporting billions of connected devices. Among the applications expected to be supported by the availability of 6G we can find critical technologies such as advanced industrial automation, autonomous vehicles and smart cities (Massaro, 2017). However, despite EU's preliminary research in the field of 6G, exp.1 sustains that EU's strong sensing capability will remain again unexploited if not followed by improved seizing through timely effective implementation. Contrarily, China has already developed early studies and strategies on 6G, taking steps forward through a significant number of investments (GSMA, 2022). The expected EU weakness in implementation would apply a reactive approach, rather than proactive, forecasting a decreased effectiveness in sensing capabilities if compared to the leadership demonstrated in 5G planning. According to epx.1, sensing does not stop at the foresight of emerging technologies like 6G, but also concerns a timely allocation of resources for spectrum management.

In conclusion, we argue that, although it encountered difficulties when it comes to strategically allocating resources, the EU has overall successfully demonstrated effective sensing capabilities, especially when it comes to predicting emerging technological trends as 5G. The approaching wave of technological innovation based on 6G deployment will provide us with additional concrete elements for examination. In this case, effectiveness in sensing will majorly depend on a more efficient allocation of resources, weak component in the 5G's sensing.

4.4 Market Demand Analysis

The second component we have individuated during our research consists in the ability of sensing evolving market demand and strategizing accordingly.

A complete alignment between spectrum policy and the needs of market segments such those of automotive, healthcare, telecommunication and smart cities is critical for designing an effective strategy to ensure availability of bands for wireless communication, backbone of such technologies. In this sense, the case of 5G represents once again a concrete tool for assessing sensing capabilities, this time in relation to predicting market demands. 5G has tremendously shifted market expectations on connectivity, being capable of supporting revolutionary industrial applications such as those of industry 4.0 like IoT, Machine-to-machine (M2M) communication and AI (Cisco Annual Internet Report, 2023). As according to exp.1, the EU has managed to recognize in advance this shift in market demand and strategically include industrial 5G deployment into its Digital Single Market strategy, promoting high-level connectivity in businesses use (European Commission, 2020).

However, as for the case of technological trend identification, even here the successful strategizing and early detection of evolving market demands (sensing phase) did not concretely convert in EU-wide coordinated implementation of spectrum policies. This is evident when analyzing DESI's 2023 broadband connectivity divide between urban and rural areas. While 90% of urban households enjoy availability of high-speed broadband, in rural areas only 66% of households have it at their disposal (DESI, 2023). Despite the effective early detection of the changing market demands, the evident disparity in broadband availability is proof of a deficiency in addressing varying market demands based on regional needs. That is why, according to exp.1, the only partial success in 5G sensing is motivated by an unsatisfying strategic planning in matching the growing demand for spectrum of the IoT market, expected to exponentially grow, with billions of interconnected devices spanning across multiple industries such as healthcare, autonomous vehicles, sensibly increased spectrum demand.

Once again, even in this case, although the EU sensing capabilities successfully predicted the shifts in demand, the strategic allocation of resources for spectrum management proved to be not fully effective in supporting the connectivity necessary to reap the maximum benefits from M2M applications (Manyika et al., 2019). Exp.2 pointed out that the deficiency in resource allocation has resulted in the EU lagging behind compared to other global players such as the USA and China, where consistent resources for IoT spectrum availability have been directly envisaged in national digital strategies. This seems to be an unlikely outcome in a fragmented context like that of the EU's, where often lie multiple conflicting national interests. As according to exp.2, contrarily to the EU, USA's Federal Communication Commission (FCC)

has successfully managed to include flexible approaches of spectrum sharing in its strategy, allowing for a more efficient market-based allocation of spectrum bands satisfying the IoT demand (FCC, 2023).

Thus, even in this case, the EU proved to possess very effective sensing capabilities in predicting market shifts in demand, as for instance those caused by 5G technology, however its struggle in strategically allocating resources based on regional needs, as for the case of IoT spectrum demand, witness the existence of room for improvement in sensing activity.

4.5 Regulatory and Competitive Landscape Monitoring

The EU's ability in effectively conducing a continuous monitoring of the regulatory and competitive landscape represents the third component we selected in our assessment of EU sensing capability in spectrum management.

Sensing is conducted both internally as well as externally, the mix of the two areas provides the comprehensive approach necessary for an effective spectrum management. More in practice, internal sensing deals with a constant monitoring of the EU regulatory environment, while external sensing with the monitoring of the global competitive landscape.

Internally, the EU faces serious challenges in attaining the wished fully harmonized regulatory framework necessary for a maximum exploitation of the Single Market's potential. For this reason, the introduction in 2018 of the European Electronic Communications Code (EECC) sought to reach a harmonized framework for spectrum management across the 27 Member States (European Parliament, 2018). However, the implementation of the EECC across the EU has shown wide inconsistency at the national level, resulting in untimely spectrum auctions and varying degrees of 5G rollouts. The fragmented regulatory implementation not only caused uneven availability of 5G services across EU regions, but also, as highlighted by exp.1, it hindered the Union's ability in monitoring and effectively responding to changing market conditions, often misaligned across borders.

This regulatory fragmentation does not only negatively affect the internal unity of the Single Market, but it also inhibits the EU's possibility to leverage its international status of market superpower in the global arena (Damro, 2012). Exp.2 underlines how competitors like USA and China have adopted a more forward-looking vision envisaging dynamic spectrum

allocation practices, able to ensure the necessary flexibility in adapting to changing market conditions. More specifically, the USA, under the coordination of the FCC, showcased innovation capabilities by allowing spectrum-sharing models which permit multiple users to exploit the same frequency bands without interference (FCC, 2021). This forward-looking sensing of the necessity to adapt the regulatory framework by incorporating new regulations into its national strategy, has allowed the USA to outpace the EU in coverage, penetration and rollout of 5G, key in ensuring market competitiveness. This early success of the USA approach is reflected in the findings of the Ericsson 2023 mobility report, comprehensive research published annually by Ericsson (leader in telecommunications and services) detailing the current trends and future forecasts in the mobile industry, devoting special scrutiny to technological advancements like those in 5G. According to the report, 5G global network coverage will reach 85% of the population by 2028, in this sense the USA are already well above the threshold with 95% of the population covered, while the EU is significantly lagging behind with around 70% in 2023 and an expected increment up to 80/85% by 2028, barely matching the study's threshold in its most wishful forecast (Ericsson, 2023). China, on the other hand, managed to successfully deploy wide coverage thanks to state-led heavy investments in digital infrastructures. China's strongly centralized framework of governance, contrarily to the EU's, enabled a streamlined and coordinated rollout of spectrum allocation policies. Moreover, the GSMA reports that the early investments in 5G have already started to yield dividends, with almost total coverage by 2023, potentially adding 1.3€ trillion to China's GDP by 2030 (GSMA, 2023). On the other side, as noted by exp.3, despite the existence of an institutionalized forum for coordination under the form of the Radio Spectrum Policy Group (RSPG), the EU lack of centralized authority, contrarily to the FCC in the USA and the Ministry of Industry and Information Technology (MIIT) in China, hinders the swiftness of EU's response to global competitive pressures. Always according to exp.3, the EU multi-layered governance framework, while apt in protecting member states' national interests, does not possess the necessary tools to guarantee national coordination through effective enforcement, recurring phenomenon in areas of shared competence such as that of spectrum.

4.6 Assessment of Sensing Capabilities

The assessment of EU sensing capabilities furnishes us a with a mixed picture, although we argue to be a predominantly positive one. The EU has widely demonstrated its ability in predicting newly emerging technological trends and in designing comprehensive strategies, for

example by launching key projects such as the *5G Action Plan* and incorporating spectrum policies in its digital strategy. However, the EU has not managed to fully exploit its predicting ability. Too often, delays in implementation, inefficient allocation of resources and regulatory fragmentation have characterized the sensing of the EU, critical phase in supporting the emergence of newly revolutionary technologies such as 6G and AI-driven innovation.

Among the strengths we detect:

- **Effective predicting and strategic planning**: the EU proved to be successful in early recognition of the importance of 5G and launched strategic comprehensive initiatives like the 5G Action Plan.
- **Stakeholder engagement and data driven action**: The EU governance envisages critical fora for information sharing among stakeholders and experts of the sector to support policymaking, such as the RSPG. In addition, tools like the European 5G Observatory permit a data-driven approach in monitoring, fundamental in early detection of shifting market demands.

Among the weaknesses we detect:

- **Regulatory fragmentation**: The unsatisfactory harmonized transpositon of EU-wide digital strategy in national regulatory frameworks impedes the full exploitation of cross-border benefits of wireless technologies. This leads to structurally differring market demands based on countries, making preemptive sensing more difficult.
- **Lacking strategic planning of innovative spectrum sharing practices**: EU sensing, contrarily to the USA's, proved not to be able to include innovative spectrum sharing practices in its strategy. The decentralized EU regulatory approach in implementation has proved to be incapable of adopting these innovative approaches.

4.7 Seizing Capabilities in EU Spectrum Management

Also for seizing capabilities our research detected three main components which, once assessed through the lenses of Dynamic Capabilities Theory, will provide us with a complete picture of the EU spectrum management.

Seizing represents the phase following sensing, where the EU applies its ability in capturing opportunities and making practical use of the insights gained through sensing. This section analyzes three components individuated during the research, namely the effectiveness in

implementing spectrum assignment strategies and regulatory frameworks and promoting Public-Private collaboration for bolstering investments in digital infrastructures.

4.8 Spectrum Assignment Strategies

As detailly explained in our technical spectrum 101 of chapter 1, once a certain band has been allocated, then the assignment phase takes place, often under the form of competitive auctions. Spectrum assignment represents the cornerstone of EU's seizing capabilities, determining the efficiency in the distribution of spectrum bands for accomodating innovative technologies.

Since 2018, the European Electronic Communications Code (EECC) has provided the common playground onto which harmonization among Member States should take place. It specifically built on the strategies outlined in the 5G Action Plan to target the assignment of 5G pioneer bands (700 MHz, 3.6 GHz, and 26 GHz) (European Parliament, 2018). The intention here was to set a common regulatory framework to facilitate the deployment of 5G technologies, critical element for the competitiveness of the Single Market. However, the existence of the EECC, clearly defining the regulatory framework, did not prevent the inconsistent and fragmented spectrum assignment witnessed in the EU. Exp.1 underlined the significant delays in countries like Poland and Greece where political instability and lack of regulatory coordination created a non predictable market for spectrum, negatively impacting the attractiveness of the countries' economies. On the other hand, always exp.1 indicated countries such as Finland, Germany and Italy as best practices in 5G spectrum auctions. The potential benefits of a well-executed spectrum auction stretch more than just the private sector business, also including the public sector. German's 2019 and Italian's 2018 auctions raised respectively approximately €6.5 billion and 6.55€ billion, demonstrating the importance of a well-executed seizing in providing consistent financial support for public investements in digital infrastructures (European Commission, 2020) (European 5G Observatory, 2019).

Contrarily to these successful cases, spectrum auctions in countries like Poland created an uneven landscape in bands availability, preventing a truly functioning Single Digital Market across the EU. For instance, Polish 5G auction was delayed multiple times, initially due to regulatory disagreements and later due to the COVID-19 pandemic. This led to a largely untimely 5G deployment, which only took place starting from the end of 2020 (GSMA Intelligence, 2020). Greece constitutes an additional example of inefficient assignment, where economic struggles and political instability delayed auctions, provoking late deployment of 5G

connectivity, critical in sustaining the country's sluggish economic recovery (European Commission, 202).

The largely uncoordinated and fragmented execution of spectrum auctions does not represent the only flaw in EU's spectrum seizing capabilities in assignment. The Union's bureaucratic rigidity is an additional point of concern, especially when dealing with highly dynamic environments as that of digital technologies. As exp.3 pointed out: "*an efficient spectrum assignment process does not only deal with procedures, such as the rules regulating the stages of spectrum auctions, but also with a constant capability in adapting to market needs, as it happened in the USA with spectrum-sharing models*". In this sense, the Union's approach based on shared consensus proved to be overly bureaucratic, with little power of initiative at the central level. This procedural stifness in decisionmaking has caused the EU strategy not to be flexible enough for new methods of spectrum use as that of spectrum-sharing, permitting the USA to be forerunner in these innovative more efficient practices. In this sense, exp.3 underlined the proactive role of the USA's FCC which, contrarily to the EU case, has demonstrated the necessary flexibility for embracing spectrum-sharing models with the Citizens Broadband Radio Service (CBRS), a wireless communication band allowing dynamic sharing in the 3.5 GHz range among multiple users, both private as well as federal (FCC, 2021). This flexibility in seizing has enabled the USA to be more agile in deploying 5G networks vis a vis the EU, notably in more densely inhabitated areas where demand is highest.

In sum, while the EU has taken several steps forward in coordination of spectrum assignment strategies, most notably with the adoption of the EECC, the slow and inconsistent pace of spectrum auctions, coupled with the lack of the regulatory flexibility necessary for envisaging new spectrum sharing models, has hindered 5G rollout across the Union, negatively affecting the level of connectivity and competitiveness of the Single Market.

4.9 Regulatory Framework Implementation

A well-executed implementation of the regulatory framework is key for enabling spectrum policies to be transposed in concrete seizing actions.

The EECC was indeed originally designed to provide a common regulatory framework for streamlining spectrum assignment and creating a level playing field for 5G deployment across the Union (European Parliament, 2018). However, despite the primary importance of the goals

enshrined in the EECC design, both exp.1 and exp.3 observed that its implementation across Member states has proved to be slower and more fragmented than expected.

In particular, exp.3 shared the vision that, although bureaucratic rigidity consitutes a concrete issue, the lack of efficiency in the implementation of the EECC is mainly a consequence of the varying degrees of readiness and capability of Member States in adopting and enforcing the provided regulatory framework. National-level politics and economics in this case do play a significant role by either facilitating or delaying implemetation based on national priorities. While in countries with well-established national regulatory authorities and strong political will, such as Germany and Finland, the national regulatory framework quickly aligned with that of the the EECC, on the other hand it has not proven to be the case in regions such as southern and eastern Europe, where political and economic instability caused significant delays in spectrum assignment (as noted in the Polish and Greek cases).

In addition, the national differences in the level of financial and technical capabilities strongly influenced the adoption of the EECC at the state level. The considerable infrastructural investments required for 5G deployment can potentially represent an insurmountable barrier in economically weaker countries, with governments exhibiting low political will in allocating the necessary financial resources. Despite EU-led initiatives such as the Connecting Europe Facility, which puts at the disposal of Member States technical support and funding, some countries still struggle in attracting the private investments necessary for large scale 5G deployment. Specifically, in economically weaker countries, the investments required for 5G infrastructures can result to be a deterrent, with governments hesitant to allocate the necessary resources. This financial disparity paved the way for uneven regional 5G coverage, with rural areas notably affected by underdevelopment in digital infrastructures.

4.10 Public-Private collaboration

During our research, we have comprehended how vital the role of Public-Private Partnerships (PPPs) in fostering seizing capabilities is, especially when it comes to financing and deploying 5G infrastructures.

Digital infrastructures constitute the backbone of connectivity, however they require a significant level of investments hardly attainable by just private or public entities alone. PPPs

play a determinant role in overcoming financial and logistical barriers by pooling together the necessary resources (financial, knowledge etc…) for achieving the level of investments required for the setting up of modern digital infrastructures.

Over the years, the EU has launched projects such as those of Connecting Europe Facility (CEF) and the European Structural and Investment Funds (ESIF) aiming at providing funding for digital infrastructural investments, especially focusing on underserved areas (European Commission, 2020). However, these funding strategies are majorly designed to bolstering public investements and, as according to exp.3, lack the necessary efforts in directly engaging with private actors for structural collaboration. As these efforts proved not to be sufficiently effective in reaching EU's ambitious goals in 5G investments, state-led PPSs have become essential elements in bridging the investment gap, combining public funding with capital and expertise of the private sector. Countries like Germany have successfully managed to reinvest a consistent part of the 6.5€ billions spectrum auction's revenues in newly launched PPPs in digital infrastructures under the supervision of the Federal Ministry of Transport and Digital Infrastructure (BMVI), working shoulder to shoulder with telecoms companies to ensure an efficient broadband rollout.

However, state-led initiative typically do not aim at a balanced unfolding of PPPs across the whole Union, but rather are designed accordingly to a narrower focus based on national priorities. That is why, despite the EU-centred efforts, exp.1 underlined the existence of markedly inconsistent level of private sector involvement across different countries, with more rural regions promising lower financial return on infrastructure investments, complicating the pooling of private fundings. On the other hand, the USA proved to be more effective in systematically including PPPs in its seizing action to expand digital infrastructures. Among others, it passed in 2021 the Infrastructure Investment and Jobs Act (IIJA), allocating over $65 billion for broadband deployment, with a significant portion of the funds allocated for sustaining private sector's investments (FCC, 2023).

4.11 Assessment of Seizing Capabilities

In summary, as in the case of sensing, also the analysis of the EU's seizing capabilities provides us with a mixed-picture composed of both strenghts and weaknesses in the EU spectrum management. However, while the final overall assessment of sensing capabilities leaned more on the positive end, here we argue the seizing phase to majorly lack the dynamic capabilities

necessary for its effective unfolding. In particular, the EU's seizing capabilities are hindered by a combination of sub-optimal spectrum assignment strategies, a too weak implementation of the harmonized regulatory framework and an insufficient public-private collaboration for investments in digital infrastructures. Despite the significant steps forward achieved by the EU in these areas, especially thanks to EU-led legislative initiatives like the EECC and funding projects like the CEF, these efforts have been systemically undermined by a weak implementation at the Member State level, key element for a truly effective seizing process.

Among the strengths we detect:

- **Shared regulatory framework**: The European Electronic Communications Code (EECC) constitutes the shared legal foundation for spectrum assignment and digital infrastructure development.
- **EU-led public funding initiatives**: The Connecting Europe Facility (CEF) and the European Structural and Investment Funds (ESIF) have both played a key role in funding public investments in digital infrastructures, especially in underserved areas.

Among the weaknesses we detect:

- **Delays and lacking harmonization in spectrum assignment**: the lack of harmonization in spectrum assignment procedures has led to consistent disparities in 5G deployment, most notable in economically weaker countries where multiple factors contributed in significantly delaying spectrum auctions.
- **Lack of regulatory flexibility**: The EU's overly bureaucratic rigid regulatory framework proved not to be flexible enough in accomodating shifting market demands through forward-looking amendments in regulations, not envisaging innovative approaches such as spectrum-sharing models.
- **Insufficient public-private collaboration**: The EU-led initiatives have not envisaged a structural inclusion of PPPs, focusing primarily on public investments. PPPs mainly took place at the state level, enlarging the investment gap between between regions.

4.12 Transforming Capabilities in EU Spectrum Management

Transforming Capabilities constitute the third and final element of our assessment on the effectiveness of EU spectrum management. Transforming capabilities, as according to David Teece's definition, refer to the "*continuous renewal of the organization through*

reconfiguration, recombination, and redeployment of resources, capabilities, and structures to address new market opportunities or challenges." (Teece, 2007).

In the context of our research, this stage coincides with the EU ability to adapt and reconfigure its regulatory framework, policy direction and resources according to changing conditions. In particular, our research argues that EU transforming capabilities mainly depend on two factors, namely the aptness of the governance system in reconfiguring the regulatory framework and the perpetual organizational learning based on stakeholder engagement.

4.13 Regulatory Adaptation and Flexibility

In any organization, regulatory adaptation is strongly dependent on the level of flexibility allowed by the ruling governance framework. Specifically, in the EU the ability in regulatory adaptation is intrinsically linked to the consensus-based decision-making approach, cornerstone of the Union's governance. The EU, specifically for what concerns areas of shared competences such as that of spectrum management, heavily relies on reaching widespread accord among national governments before adopting amendments to the regulatory framework. This consensus-driven system of governance has taken form during the process of European integration to promote the common EU-wide interest while always respecting the national sovereignty of each of the (currently) 27 Member States (Bickerton 2015). The necessity of including multiple (often disaligned) interests in a commonly agreed action plan inevitably slows the process of regulatory adaptation (Bertelsmann Stiftung, 2021).

Once again, the European Electronic Communications Code (EECC) provides us with a concrete element of analysis, showcasing how the consensus-based governance approach has affected spectrum management. Although the EECC specifically aimed at harmonizing spectrum assignment across the Union, differing national priorities and regulatory frameworks have impeded the Commission's wish of complete harmonization. Member States' considerable autonomy in areas under shared competence, has permitted them to set national roadmaps in spectrum assignment with differing timelines based on national priorities. As according to Bohlin et al., 2020, the significant delays in 5G spectrum auctions experienced in Poland and Greece were a direct consequence both of internal political and economical struggles (as already pointed out in the seizing section), but also of the consensus-based nature of EU regulatory implementation, significantly lacking credibility in enforcement. In addition, once reached the necessary unanimity among Member States, often the compromises dilute the

boldness of objectives and ambitiousness in deployment rapidity of policies. This necessity of "compromising to the bottom" characterizes the decentralized consensus-driven EU approach, profoundly different from systems like the USA where a centralized regulatory body as the FCC has the authority to timely implement spectrum policies without the constant need of greenligthing from the different layers of governance (Marcus, 2020). On the other side, the EU systemically relies on a multi-layered framework of governance where various stakeholders, from the EU institutions to industry, from nation states' governments to regulatory authorities, advocate for distinct policy priorities, making it difficult to fastly implement innovative spectrum strategies such as spectrum-sharing models. As according to Guerin, 2017, this regulatory rigidity deriving from the EU system of governance not only has a potential negative impact on 5G deployment, but also hinders the EU ability in rapidly adapting to emerging technologies like 6G and IoT, central component of transformation capabilities.

However, we should point out that the EU consensus-driven approach does not represent an ineffective system of governance per se, but rather we argue to be unsuccessful specifically in relation to the management of rapidly changing dynamic environments, like that of emerging technologies relying on spectrum availability. Academic research has demonstrated the consensus-driven governance approach to be highly effective in securing the necessary conditions for long-term stability of political systems, however lacking efficacy in short term adaptation and response, where a more centralized decisionmaking approach would be preferable (de Vries, 2018).

In sum, regulatory adaptation and flexibility, key components of EU's transforming capabilities, are strongly dependent on the structure of the organization's governance. In the context of the EU, while the consensus-driven governance framework proves to be carefully suited in simultaneously accomodating Member States' differing interests, however it also represents a primary reason for unresponsiveness in spectrum management adaptation. These elements altogether negatively impact the transforming capabilities of the EU, consequentially hindering competitiveness in the digital economy.

4.14 Organizational Learning

Organizational learning in the context of the EU spectrum management is deeply dependent on an effective stakeholders engagement at all level of governance.

The EU spectrum management multi-layered framework encapsulates in its nature the involvement of various stakeholders such as public and institutional bodies, private companies and civil society organizations. This design envisages a continuous bidirectional exchange of expertise, facilitating the final decisional outcome to be truly reflective of stakeholder's multiplicity of interests.

In the context of EU spectrum management, the Radio Spectrum Policy Group (RSPG) provides a pivotal institutionalized platform for facilitating stakeholders engagement, contributing to the design and implementation of spectrum policies across the Union (European Commission, 2019). However, while this approach permits the RSPG to be an effective tool for coherently channelling the stakeholder's mulitple interests into inclusive policies, its capability in shaping concrete actions to enhance the EU's organizational learning has proved to be weakened by the consensus-driven regulatory approach, often resulting in diluted or delayed policy outcomes (Massaro, 2017).

The required decisional unanimity, combined with the lenghty consultation processes, frequently leads to sensible delays in decision-making and implementation, resulting in ineffective transforming capabilities in adjusting the direction of spectrum policies.

In this sense, the 5G Action Plan provides a relevant tool for assessing EU's transforming capabilities. Since its inception, the 5G Action Plan has been designed to early include stakeholders in strategic planning. This approach aimed at improving public-private coordination to avoid the serious delays experienced in 4G rollout (European Commission, 2016). Thus, we could argue this tool to be showcasing a remarkable organizational learning in the EU spectrum management, as unsucceses from past experiences triggered organizational learning. However, exp.3 noted that, in the case of 5G rollout, despite significant improvements in engagement with private telecommunications companies, the transforming capabilities of the EU have not managed to include the whole body of stakeholders of the market. As according to Cave and Webb (2015), the EU stakeholder engagement process tends to primarily interact with well-established players of the sector, preventing the smaller entities to effectively shape policy outcomes. Exp.2 confirmed this insight as he noted that large telecoms players such as Deutsche Telekom or Orange have a markedly more influential role in consultation if compared to SMEs and startups. The disparity in treatment tends to favour the current status quo, with the well-established players lobbying for maintaining their priviledged power position. This influential imbalance demonstrates that, despite organizational learning is indeed

present in the EU governance framework, it is not always based on an all-encompassing stakeholder engagement, consequently lacking the forward-looking innovative vision typical of rising companies and startups.

As according to exp.2, the early adoption of spectrum-sharing in the USA also comes from an effective organizational learning, able to evolve its approach by integrating feedback from forward-looking stakeholders. In fact, exp.2 noted that the FCC has proved a strong willingness in engaging with tech startups and innovative SMEs, both entities capable of rapidly adopting spectrum-sharing models. On the other side, the EU has struggled to follow the FCC's example. Although the potential deployment of spectrum sharing models has been discussed in the RSPG forum, as of 2023 the EU has not taken decisive actions in this direction, showcasing mixed results in terms of organizational learning.

In conclusion, while the wide stakeholder engagement envisaged in the EU governance framework constitutes a pivotal component in fostering organizational learning and continuous improvement, its effectiveness is often weakened by the Union's consensus-driven decisionmaking approach. The fruitful engagement with well-established players of the sector constitutes for the EU a valuable resource in terms of expertise and knowledge sharing, key components in organizational learning. However, the difficulties experienced by smaller realities, such as tech startups, in providing influential inputs for the decision-making process, has kept the EU spectrum management approach somewhat conservative, keen on ensuring stability rather than supporting swift adaptation to technological developments. This resulted in a lack of forward-looking innovative approaches to radio spectrum management, as for instance that of spectrum-sharing. In sum, we argue the EU governance framework to be fit for organizational learning thanks to its inclusive nature fostering stakeholder engagement. However we also argue that, although the Union disposes of the right tools in supporting transforming capabilities through organizational learning, the current mechanism of stakeholder engagement needs to be improved by streamlining procedures and ensuring the inclusion in the decision-making of inputs coming from a more diverse variety of voices.

4.15 Assessment of Transforming Capabilities

Overall, also the assessment of EU's transforming capabilities depicts a picure of mixed results. While the EU possesses the necessary tools for supporting regulatory adaptation and organizational learning, such as the EECC and the RSPG, we have however assessed that the

EU consensus-driven governance framework is often conducive to a overly complex reforming mechanism, characterized by slow-paced regulatory adaptation and lack of the forward-looking organizational learning necessary in transforming the regulatory framework and keeping pace with technological advancements.

Strengths:

- **A comprehensive common regulatory framework**: the EECC constitutes, at least on paper, a well-tailored tool for ensuring regulatory harmonization and coordination in spectrum assignment.
- **Collaborative learning fora**: entities such as the RSPG allow for knowledge-sharing and systemic stakeholder engagement, providing sound inputs in support of the decision-making process.

Weaknesses:

- **Consensus-driven governance framework**: the EU consensus-driven governance, although serving vital political needs of the Union, does not ensure enough rapidity in regulatory adaptation to extremely dynamic contexts such as that of the digital economy.
- **Fragmented implementation**: the fragmented landscape of the Single Market hinders coordination in implementation (ex. auctions) and the development of cross-border services.
- **Disparity in stakeholder engagement**: the lack of inclusion of SMEs and startups in stakeholder engagement, in favour of well-established market subjects, deprives the EU decision-making of critical forward-looking innovation-based inputs on spectrum management.

4.16 Summary of Findings: Key Insights from Sensing, Seizing, and Transforming

Our assessment of EU radio spectrum management through the lenses of Dynamic Capabilities Theory has pictured a complex mix of strenghts and weaknesses in each of the sensing, seizing and transforming phases.

In terms of sensing capabilities, we have assessed a notable efficacy in early recognizing emerging trends of critical technologies such as 5G, IoT, AI and the rapidly incoming 6G. The 5G Action Plan provides us with a valuable example of a EU-led program which has showcased strong abilities in early strategizing and foreseeing shifting market demands, successfully setting the ground for the EU's tackling of such phenomenon.

However, starting from the seizing capabilities' phase, our assessment has taken a more negative downsloping direction. The nationally-based management of allocation and assignment strategies has failed to effectively provide the necessary coordination for reaping the benefits of spectrum-based technologies, with Greece and Poland providing us with clear examples of significant delays in spectrum auctions (Bohlin et al., 2020). Finally, also transforming capabilities have struggled to fully develop, as the EU consensus-driven governance framework and the deficient inclusive stakeholder engagement have made regulatory adaptation slow, especially when compared to more centralized approaches like that of the USA (Marcus, 2020).

Dynamic Capability	**Strengths**	**Weaknesses**
Sensing ✓	- Effective predicting and strategic planning - Stakeholder engagement and data driven action	- Regulatory fragmentation - Lacking strategic planning of innovative spectrum sharing practices
Seizing ✗	- Shared regulatory framework - EU-led public funding initiatives	- Delays and lacking harmonization in spectrum assignment - Lack of regulatory flexibility - Insufficient public-private collaboration
Transforming ✗	- A comprehensive common regulatory framework - Collaborative learning fora	- Consensus-driven governance framework - Fragmented implementation - Disparity in stakeholder engagement

Table 2 – Summary of Strengths and Weaknesses in Dynamic Capabilities

4.17 Overall Impact on Connectivity and Competitiveness

The spectrum management of the EU systemically impacts the current status of digital connectivity and global competitiveness of the Single Market. Our dynamic capabilities' assessment has highlighted those weak areas in spectrum management (especially in seizing and transforming) that have contributed to the downlosping trend in competitiveness described in ch.2.

Spectrum delays and lacking harmonization across Member States have resulted in uneven 5G rollout, with notable regional disparities in coverage and availability of broadband, all elements contributing to the EU weakening position in the global digital economy. The DESI 2023 report provides us with a comprehensive overview of the significant deficiencies in service across the Union, where only 66% of the EU's population had access to 5G services as of mid-2023 (European 5G Observatory, 2023). The negative effects on the status of EU competitiveness have also been clearly highlighted in the World Economic Forum's Global Competitiveness Report (2023), where the EU trails behind China and the USA in the adoption of ICT and availability of modern and reliable digital infrastructures. In these cases, the more centralized governance of spectrum has enabled these global competitors to move rapidly ahead in the race for 5G, successfully supporting the adoption of emerging digital technologies and fostering innovation.

Chapter 5: Comparative Analysis of Spectrum Management in the EU and USA: Innovation, Flexibility, and Policy Recommendations

5.1 A "Diverse Case Study" Cross-country Comparative Analysis

In chapter 5, we will conduct a cross-country comparative analysis of the spectrum management between the EU and the USA. The theoretical exercise will take place within the analytical framework of Seawright and Gerring (2008)'s "Diverse Case Study" methodology. This conceptual instrument consents to conduct a comprehensive comparison between systems that differ in key dimensions, in our case being the EU decentralized, multi-layered, consensus-driven and the USA's centralized, federal, market-based approach in spectrum management.

The aim of the chapter is to first, outline the structural differences between the two models and, once elucidated, to second proceed in comparatively assessing the effectiveness of the USA's seizing and transforming capabilities, which we argued to be the components the EU is lacking (see chapter 4). The following analysis will draw insights on the effects of the two governance frameworks on core elements of spectrum management, including assignment strategies, regulatory flexibility and innovation capabilities.

Ultimately, this analysis ends with a concluding forward-looking section outlining policy recommendations to improve the effectiveness of EU spectrum management in support of digital competitiveness. These proposals will majorly draw from USA's best practices in the assessed critical areas.

The comparative analysis follows a logical structure that mirrors the key dimensions that we consider to be pivotal in spectrum management. First, we evaluate the regulatory frameworks of the EU and the USA, enquiring how the centralization/decentralization feature influences efficiency. Subsequently, we delve into spectrum allocation and assignment strategies, central component of seizing. Next, we turn to the assessment of technological innovation and flexibility, both relevant elements in determining regional responses to market and technological shifts. Afterward, we proceed in evaluating the ability in converting strategies into actions during seizing, through the assessment of spectrum assignment and regulatory

implementation. Finally, we analyze transforming capabilities by considering key elements such as regulatory adaptation, organizational learning and the ability to foster innovation. This logical structure of the comparative analysis will permit us to systemically examine the differences in spectrum management approaches, reflecting the principal components of dynamic capabilities discussed in previous chapters.

5.2 The “Diverse Case Study” Framework of Analysis

The "Diverse Case Study" (DCS) selection methodology serves to conduct a tailored comparison between case studies differing in key dimensions but share a common challenge or objective. Seawright and Gerring (2008) argue this methodology to be highly successful in capturing the set of factors influencing a given outcome in dissimilar contexts, helping to individuate which mechanisms may be at play.

In our research on EU spectrum management, we selected the USA as the “diverse case” to compare the differing approaches. While the two subjects display sharp differences in relation to spectrum management mechanisms, they however both aim at the same goal, namely to promote an efficient spectrum management in support of digital competitiveness and innovation. For the sake of completeness, we report that China has also been taken under consideration as an additional “diverse case”. However, we argue that the too divergent governance structure of the Chinese state would have made our analysis, especially in the section of policy recommendations, less applicable.

5.3 EU-USA Spectrum Management Comparative Analysis

In the following section we will conduct the cross-country comparison between the two models of spectrum management. This exercise will provide us with a detailed understanding of the key elements distinguishing the two approaches. More specifically, we will delve into the differences in approaches and outcomes related to regulatory frameworks, spectrum allocation and assignment strategies and, technological innovation and flexibility.

Our assessment will be framed in the temporal span stretching from 2002, year when the RSPG was conceived, to almost present time as we will evaluate recent reports such as the DESI 2023. However, we should acknowledge that the temporal focus of our comparison starts from the 1st

of December 2009, day in which the Lisbon Treaty came into effect reiterating the shared competence nature of spectrum management.

5.4 Regulatory Framework: Centralization vs. Decentralization

The level of centralization of regulatory authority constitutes a critical element in determining the effectiveness of spectrum management activity. The EU adopts a complex consensus-based, multi-layered structure of spectrum governance. The Commission, through means of legislative acts such as the EECC, has increasingly attempted to harmonize spectrum assignment across Member States, also by leveraging its 'right of initiative", pillar element in the EU legislative process. However, as we have seen in chapter 4, implementation at the national level has proved to be inefficient and uncoordinated, with states' governments conducting spectrum auctions principally according to national interests (as in the Greek and Polish cases previously analysed) (European 5G Observatory, 2023). This fragmented regulatory landscape showcases the strongly decentralized nature of seizing in the EU governance framework which, as according to exp. 3, is the root cause of its weak seizing and transforming capabilities.

The strand of views arguing decentralization to be unfit for governing spectrum management is also supported by concrete quantitative findings. The DESI report highlights sharp disparities in rates of 5G availability between Member States, mainly caused by delayed and uncoordinated auctions. By mid 2023, only 66% of the EU population had access to 5G services, denoting markedly low levels in rural areas (DESI, 2023). The decentralized fashion of EU spectrum management represents the cause at the root of Member States' extensive autonomy of action, making spectrum harmonization troublesome across the Union.

By contrast, the USA's centralized regulatory governance model results to be well-suited for spectrum management. More specifically, the FCC's streamlined procedures and effective enforcement ensure timely auctions and regulatory consistency across the States. The aptness of the USA's centralized approach is concretely reflected in quantitative findings such as those related to 5G coverage. The USA has achieved 95% population coverage by mid-2023, a significantly higher rate if compared to the Union where the digit stops at 66%, clearly showcasing the EU's inferior achievements, fruit of its decentralized approach in spectrum governance (Ericsson Mobility Report, 2023).

Procedural rapidity does not represent the only benefit resulting from a more centralized approach. The FCC's early inclusion (already in 2020) of spectrum-sharing model in the Citizens Broadband Radio Service (CBRS), demonstrated a significant degree of flexibility in support of the adoption of innovation (FCC, 2021). The flexibility granted by the USA's centralized governance model has enabled the FCC to meet the evolution of market demand for connectivity, efficaciously tackling the incumbent challenge of spectrum scarcity.

5.5 Spectrum Allocation and Assignment Strategies

Allocation and assignment strategies, both key in ensuring successful spectrum management, constitute the second element differentiating the two respective approaches.

In the EU, the EECC was adopted for streamlining both procedures and increasing the level of harmonization across the borders of the Single Market. However, as thoroughly analyzed in chapter 4, the EU approach in spectrum management did not prove to be effective in fostering seizing capabilities, with the national spectrum auctions characterized by delays in assignment of critical bands for 5G rollout, particularly in the 700 MHz, 3.6 GHz, and 26 GHz bands, this happened for example in the Polish case where political uncertainty and inefficient 5G auctions pushed back 5G services by several years (European 5G Observatory, 2023). On the other hand, states like Germany and Italy managed to carry out timely auctions, raising respectively €6.5 billion and €6.55 billion in 2019 and 2018, showcasing the noteworthy financial benefits deriving from well-executed auctions. However, not all the Member States possess the features (political willingness, socio-economic stability, technical expertise etc…) necessary for seizing capabilities to conduct efficient spectrum auctions, resulting in significant disparities in 5G coverage across regions. In sum, the deficiencies demonstrated by the nationally based model of spectrum auctions directly curtail EU's Single Market digital competitiveness.

The USA, contrarily to the nationally based interest-led EU governance, has adopted a more flexible market-driven approach in spectrum allocation and assignment. The FCC, by holding competitive auctions on a rolling basis, puts at disposal of private and public operators the necessary bands for their services, circumventing inefficiencies caused by unutilized spectrum bands. In 2020, FCC carried out Auction 105 (also named CBRS Auction) to meet market demand for mid-band spectrum. The successful assignment of the 3.5 GHz band in support of 5G services permitted the USA to accommodate the shifting market demands, meanwhile raising over $4.5 billion in revenues (FCC, 2021).

We can now clearly spotlight the difference between the EU and USA's approaches in assignment strategies, where the USA's market-driven flexibility in auctions, along with the FCC's authority in swiftly adapting rules and strategies, has made spectrum management more agile vis a vis the EU. This feature has led the USA to early championing innovative models of spectrum-sharing. The CBRS, as mentioned earlier, allows for a more efficient use of spectrum bands by enabling the coexistence of multiple users, including private companies and federal agencies.

In sum, the FCC's market-driven willingness to experiment innovative models of assignment, coupled with its centralized authority, has permitted the USA to preemptively address the obstacle of spectrum scarcity, current matter of great concern given the surging number of interconnected devices.

5.6 Technological Innovation and Flexibility

Technological innovation lies at the core of both the EU and the USA's spectrum management policies, however their approach in facilitating and managing the adoption of new technologies differs significantly. These dissimilarities primarily consist in diverging regulatory philosophies, which in turn lead to different outcomes in terms of adaptation to new technologies and market demands. In this regard, a high level of governance flexibility is critical, as it permits to successfully adapt to the continuously evolving technological conditions.

More specifically, the EU approach to technological innovation is characterized by long-term strategic initiatives such as the case of the 5G Action Plan. However, our analysis in chapter 4 has outlined that the UE consensus-driven governance structure, although functional to securing political inclusiveness, hampers the capability of translating these strategies into concrete policy actions. Such structural challenge leads to fragemented implementation across Member States, adding complexity to the already multilayered EU system of spectrum management.

The bureaucratic rigidity inherent of this governance structure directly impact regulatory flexibility, essential element in adapting to technological innovation. The amendment procedure often requires lengthy negotiations, resulting in consensus-based compromises

between the 27 Member States. This complex process is ill-equipped to cope with the pace of technological innovation, which instead requires bureaucratic agility.

By contrast, the USA's approach is based on a more centralized and flexible regulatory framework under the authority of the FCC, which adopts a more proactive style of regulatory philosophy vis a vis the EU's.

The 2018 "5G FAST Plan", a comprehensive strategy to Facilitate America's Superiority in 5G Technology, substantiate our observation. As according to the the FCC, the strategy includes three key components: (1) pushing more spectrum into the marketplace; (2) updating infrastructure policy; and (3) modernizing outdated regulations (FCC, 2020). The achievement of the three components would contribute to streamlining the deployment of 5G infrastructures by updating policy regulations, removing regulatory barriers, accelerating the approval for new technologies and sustaining investments in digital infrastructures (FCC, 2020). The 5G FAST Plan constitutes a concrete example of the FCC's proactive regulatory philosophy, focusing on removing the obstacles hindering market-driven solutions.

This proactive approach would have not been possible through a decentralized governance system such as that in place in the EU. The FCC's centralized decisionmaking allows for preventive action, avoiding the procedural hurdels across multiple jurisdictions characterizing the EU's reactive regulatory approach. Moreover, FCC's proactive style of regulatory philosophy is also reflected in the flexibility showcased through implementation of innovative approaches of spectrum management, as in the CBRS. This forward-looking stance in spectrum management has permitted the USA to capitalize on technological advancement ahead of the EU, securing higher level of efficiency in spectrum usage.

Additionally, the proactive approach of the FCC is also reflected in its ability to facilitate extensive collaboration with private sector stakeholders. This feature permits the USA's market to be more attractive for business investments, key element in the development of modern digital infrastructures. The FCC's proactive engagement with private actors stands in sharp contrast with the EU's more top-down approach, where EU-led funding initiatives are pivotal instruments in the development of infrastructures. Rollout of initiatives like the Connecting Europe Facility (CEF) represents a critical step in the EU roadmap for the upgrade of digital infrastructures. However, contrarily to the USA, often these funding initiatives lack a structural

involvement of the private sector, therefore missing out on investment opportunities fostering EU digital competitiveness.

In sum, the diverging approaches in technological innovation and regulatory flexiblity are direct consequence of their significantly dissimilar models of governace. While promoting long-term planning and inclusiveness in decisionmaking, the EU's decentralized, consensus-driven governance proves not to be effective in timely implementation of innovative policies, lacking the necessary flexibility for prompt adaptation to new technological applications. On the contrary, the USA is characterized by a centralized, market-driven approach which, under the authority of the FCC, is capable of carrying out a streamlined decisionmaking process, favouring quick responsiveness to newly emerging technological trends, therefore supporting the USA's quest for global digital primacy. Overall, altough clearly diverging, both the approaches stress the importance of regulatory flexibility in providing fertile ground for technological innovation, instrumental in boosting competitiveness in the global digital economy.

Having thoroughly understood the similarities and differences in the EU-USA approaches in spectrum management, we will now proceed in applying these findings to continue our comparative analysis, this time specifically in relation to seizing and transforming, which we argue to be the weak components of EU's dynamic capabilities.

5.7 Seizing Capabilities: A Comparative Analysis

Seizing in spectrum management refers to the capability of regulatory bodies in translating policy strategies into concrete actions and in creating a favourable environment for investments in digital infrastructures.

5.8 Spectrum Assignment Strategies: Regulatory Flexibility and Timeliness

Chapter 4 has given us a detailed picture of the EU's weaknesses in spectrum assignment. Seizing capabilities have been hindered by a multiplicity of factors, arguably the most critical being the uncoordinated management of auctions across Member States. In a nutshell, our analysis came to the conclusion that the EU consensus-driven governance constitutes the root cause of this deficiency, with Member States retaining a major level of autonomy on the auctions' "how" and "when". Entities like the European 5G Observatory stress the criticality

of regional disparities provoked by uncoordinated auctions, emphasizing the importance of overcoming national political and economic divisions that hinder the process. (European 5G Observatory 2023; European Commission, 2020).

By contrast, the FCC's possesses the necessary level of authority for centrally enforcing the coordination of spectrum assignment. The FCC's "Auction 105" favoured swift and efficient spectrum assignment by early allocating the 3.5 GHz band for 5G by 2020, contemporarily raising over $4.5 billion (FCC, 2021). This centralized governance system permitted the FCC to avoid "compromising to the bottom", adopting policy amendments based on shifting market conditions at a much higher pace compared to the EU. These regulatory variations, if timely implemented, permit a preventive adaptation to shifting market demands for spectrum availability.

The USA's successful seizing capability is not reflected in the EU more rigid approach, where regulatory adaptation to innovative spectrum management methods proves to be excessively slow, not keeping up with the pace of technological advancement. According to the GSMA's Global Mobile Economy Report (2023), the lack of adoption of CBRS-like methods hindered the Single Market's level of digital competitiveness by enlarging the divide in 5G deployment rate vis a vis the USA (GSMA, 2023). Moreover, the EU-USA digital divide can also be substantiated through economic elements. As according to DESI 2023, the EU stagnant GDP growth is directly affected by the lag in infrastructure readiness inhibiting 5G rollout. The efficient deployment of 5G networks represents a major factor in GDP growth, expected to benefit the global economy by more than $950 billion by 2030 (GSMA, 2023).

5.9 Public-Private Collaboration: Enhancing Investment in Digital Infrastructure

As analysed in chapter 4, PPPs constitute a critical component in driving infrastructure investments to support the strenghtening of dynamic seizing capabilities.

Both the Connecting Europe Facility (CEF) and the European Structural and Investment Funds (ESIF) have played significant role in enhancing EU public investment in digital infrastructures, achieving considerable results, especially in undeserved rural areas (European Commission, 2020). However, these public funding projects prioritized the support of public-sector-driven cross-border infrastructure projects, not foreseeing the support of private

investments as pillar of their mission. Both exp.1 and exp.2 have stressed the lack of EU proactiveness in involving private actors, in sharp contrast to what experienced from the public sector point of view. The insufficient support given to private investments has contributed to keeping return on investment low in rural areas, hindering their attractiveness for private-led projects (European 5G Observatory, 2023).

By contrast, the USA has adopted legislation like the Infrastructure Investment and Jobs Act (IIJA) which envisaged private sector engagement in its design. The IIJA allocates the significant amount of $65 billion for broadband deployment, with notable potential for private sector engagement through PPPs (FCC, 2023). The IIJA does not represent an isolated case, but it has been accompanied by additional funding initiatives which have contributed in accelerating 5G rollout in undeserved rural areas through PPPs. Among them, The FCC's Rural Digital Opportunity Fund (RDOF), launched in 2020, incentivized private investements by providing both subsidies and grants with a long-term market-driven approach. The RDOF allocated a total of $20.4 billion in subsidies and grants distributed in two phases stretching over a 10 years period. The fund aimed at supporting 5G deployment for reducing urban-rural digital divide. More specifically, it allocated in phase 1, $9.2 billion in subsidies to support investments in areas totally unserved by broadband (without access to 25/3 Mbps speeds) and succesively, in phase 2, $11.2 directed to partially served areas.

Quantative data support the effectivenss of these initiatives. The DESI 2023 reports an urban-rural divide equal to 24% in braodband coverage in the EU (resepctively 90% and 66%). In comparison, the FCC's Broadband Deployment Report (2023) indicates a minor divide equal to 15%, but the percentages in urban-rural coverage are much higher, with respectively 98% for urban areas and 83% for rural areas. The support of strong PPPs through initiatives like the RDOF helped in shrinking the digital divide responsible for regional disparities.

5.10 Regulatory Implementation: Challenges in the EU vs. Regulatory Agility in the USA

The fully coherent implementation of regulatory frameworks constitutes a critical component for strong seizing capabilities in spectrum management. Indeed, the mere existence of comprehensive harmonizing regulatory frameworks is not sufficient if the subjects under its jurisdiction retain wide discretion over its implementation.

As already outlined in chapter 4, this represents the case for the EU where, despite the comprehensiveness of the EECC, Member States retain wide autonomy in spectrum management, adjusting the "how" and "when" based on national priorities and interest. This phenomenon does not only apply to weaker political-economical contexts (as the already mentioned Polish and Greek cases) but also to economically stronger and politically more stable states such as France and Spain, which struggle in aligning national interests to the broader EU goals envisaged in the EECC. As a result, the EU's target of full 5G deployment by 2025 seems hardly attainable, adding negative momentum to the EU downsloping trend in competitiveness (European 5G Observatory 2023).

On the contrary, the FCC's greater regulatory authority secures the level of agility necessary to implement new policies in spectrum management, without the need for constant agreement between individual Member States. The effectiveness of the FCC centralized governance takes place under the form of initiatives like the 5G FAST Plan, which sets clear objectives and timeline for 5G deployment without the need of individual approval from each of the 50 States (FCC, 2023).

In sum, the FCC's agility in regulatory implementation is a direct consequence of its centralized approach, permitting continuous regulatory innovation. The GSMA Global Mobile Economy Report (2023) puts the USA's flexible regulatory framework as pillar of its digital competitiveness, outpacing both EU and China in 5G adoption. Initiatives like the CBRS and the 5G FAST Plan bear witness to the FCC success in regulatory adaptation, necessary for thriving in the dynamic digital economy (GSMA, 20239.

5.11 Transforming Capabilities: A Comparative Analysis

Transforming capabilities in spectrum management call for regulatory adaptation, organizational learning and the ability to foster innovation. Despite significant efforts in supporting a collaborative regulatory environment, the EU consensus-driven governance in areas of shared competence prevents the necessary flexibility of adaptation for effective transforming capabilities.

5.12 Regulatory Adaptation: Bureaucratic Rigidities vs. Centralized Agility

Chapter 4 has detailly outlined the inefficient design of EU governance, conducive to slow decisionmaking and slow regulatory adaptation. This result is particularly evident in relation to spectrum-sharing, which the EU has not been able to exploit as the USA did with the CBRS.

In contrast, the USA's centralized system enables the FCC to adapt its regulatory framework through centralized agility, meeting the growing spectrum demand of 5G and IoT technologies. This success is strongly backed by quantitative data stemming from the GSMA Global Mobile Economy Report (2023), which supports the fitness of the FCC's approach in regulatory adaptation. The USA is estimated to host 2.9 billion IoT connected devices by 2025, while the EU stops at 2.1 billion. In addition, the USA's mobile operators are expected to invest $275 billion in 5G infrastructure, approximately 60% more than the expected €166 billion in investements across the Single Market (GSMA Global Mobile Economy Report, 2023).

5.13 Organizational Learning: Stakeholder Engagement and Innovation

Organizational learning enables regulatory bodies to continuosly evolve based on past experiences and stakeholder feedback, making it a critical element for transforming capabilites. As already seen in chapter 4, the RSPG serves as critical platform providing an institutionalized form of stakeholder engagement in the EU, including multiple actors such as industry, civil society and national regulatory authorities riunited together to discuss spectrum policies (European Commission, 2019).

5.14 Organizational Learning: Stakeholder Engagement and Innovation

Despite the inclusive nature of the RSPG, exp.1 notes that the EU governance structure tends to grant a higher, more influential engagement with the already well-established bigger market players of the sector, undermining the possibility for smaller organizations to influence policymaking through their engagement. This lack of inclusiveness deprives the EU spectrum governance of innovative visions and practices, typical of rising smaller market players.

On the contrary, exp.2 pointed out the critical role played by the inclusiveness of the FCC's stakeholder engagement practices, which allow the collection of inputs deriving both from well-established telecoms players and smaller innovative companies. This inclusive approach is reflected in the CBRS design. The CBRS model envisages a three-tiered access structure

(Incumbent Access, Priority Access and General Authorized Acces) that allows spectrum use to a multiplicity of stakeholders. In particular, the General Authorized Access tier, by allowing spectrum access without the need of a licence, removes a critical market barrier to smaller entities, permitting them to utilize the spectrum without the risk of harmful interference.

In addition to stakeholder engagement, transforming capabilites are strongly dependent on the effectiveness of organizational learning. As analyzed in chapter 4, USA's organizational learning is facilitated by the FCC's flexibility in adaptation. The regular renewal of FCC's policies is based on a continuous assessment enabling the inputs of stakeholders to be swiftly embedded in policymaking, making possible to convert the engagement process into actionable policy outcomes.

This continuos approach in organizational learning stands in sharp contrast with the EU's rigidity of adaptation. In this case, the amendment process is dependent on the achievement of a widely shared approval resulting from lenghty consultations. Therefore, based on such premises, we argue that this systemic difference makes the USA organizational learning more effective than the EU's, enabling the implementation of more effiicent innovative solutions in the field of radio spectrum management.

5.15 Policy Recommendations: Strengthening the EU's Seizing and Transforming Capabilities

At this point, having first outlined the EU-USA differences in spectrum management and, secondly, delved with particular level of detail on USA's seizing and transforming (being the EU's weak components of dynamic capabilities in spectrum management according to our assessment), we can now turn to the more forward-looking section of our analysis by ambitiously attempting to shape policy recommendations supportive of the development of dynamic capabilities in seizing and transforming. These recommendations focus on improving regulatory flexibility, strenghtening public-private collaboration and envisaging a higher rate of inclusiveness and innovation in spectrum management.

5.16 Harmonizing Spectrum Assignment Processes Across the EU

Our first section of policy recommendations aims at improving harmonization of spectrum assignment, too often characterized by a fragmented approach at the Member States level, resulting in hindered seizing capabilities.

To achieve a more harmonized coordination of national spectrum policies, we argue that the role of the "Body of European Regulators for Electronic Communications (BEREC)" should be strenghtened with increased authority in supervising Member State coordination of auctions' timelines which, as according to Article 53(2) of the EECC should "*ensure that all spectrum available for electronic communications services is assigned in a timely manner and under conditions that optimize use in accordance with this Directive.".*

In addition, along with the strenghtened role of BEREC, we suggest the European Commission to consider the introduction of financial incentives as means to encourage Member States to conduct timely and coordinated auctions, aligning their national interests with the broader goals of the EECC. These incentives could be structured under multiple forms, specifically we believe that the Commission should leverage the already existing funding initiatives for digital infrastructures, namely the Connecting Europe Facility (CEF) and the European Structural and Investment Funds (ESIF). By providing additional funding bonuses based on the alignment of national interests with the EECC policy goals, the EU could encourage Member States to assure timely and coordinated auctions, enhancing seizing capabilities through more efficient spectrum assignment.

5.17 Embracing Spectrum-Sharing Models for a More Efficient Use

The second set of policy recommendations focuses on the adoption of innovative methods of spectrum assignment, which would enable the EU to welcome the incoming wave of new interconnected devices through improved efficiency in spectrum usage.

In this case, we recommend the EU to proactively explore the possibility of adopting spectrum-sharing methods within its legislative framework. Although this policy recommendation relates to more "technical" implications, we believe that the insights and the opinions of the experts collected in our research, along with more concrete elements drawn from quantitative reports, have provided us with the necessary elements to express a policy recommendation on spectrum-sharing models.

The successful implementation of the USA's CBRS showcases the appropiateness of spectrum sharing models in maximizing efficiency of use and accommodating spectrum demands of the new incoming 5G and IoT technologies. Thus, it is in the interest of the Union to envisage in

its regulatory framework this new method of spectrum access, perhaps following the example of the USA's model.

Even in this case, we argue that the Commission should leverage already existing resources and entities, such as the BEREC and the RSPG, to supervise the adoption of this innovative method able to strike a better balance between the large telecom companies' interests and the possibility of accessing the market for smaller operators and new entrants.

5.18 Enhancing Public-Private Partnerships (PPPs) to Boost Investments in Digital Infrastructures

Our third policy recommendation aims at reducing the urban-rural digital divide, while also supporting the deployment of digital infrastructures.

To achieve such critical goals, we recommend the EU to focus more heaviliy on the support of PPPs. Despite the Connecting Europe Facility (CEF) and the European structural and investment funds (ESIF) provided consistent public fundings in support of the deployment of digital infrastructures, there is still large room of improvement for what concerns private sector engagement.

A potential solution could lie in the establishment of an ad-hoc "*EU Digital Infrastructure Investment Fund*" which could promote private investments in undeserved areas through the provision of financial incentives. This project could envisage a funding co-financed by both European Investment Bank (EIB) and the European Commission, so to gain the necessary spotlight to attract private capital investments in underserved areas. In this sense, the USA's Rural Digital Opportunity Fund (RDOF) represents a best-practice model of a functioning mechanism which has contributed in shrinking the urban-rural digital divide, offering grants and subsidies to private actors investing in rural broadband infrastructures.

The EU, also based on the successful model of the RDOF, could introduce similar financial incentives to encourage private investments through EU-led PPPs, critical element for economic growth of the Single Market as, according to (ITU, 2021), *a 10 per cent increase in fixed broadband penetration drives 0.77 per cent growth in GDP per capita (figures tends to be higher in developed economies).* This potential positive effect in terms of GDP growth

underlines the pivotal importance of supporting public-private collaboration within the framework of a EU-wide digital strategy.

5.19 Streamlining Regulatory Processes for Faster Adaptation

Our final policy recommendation focuses on addressing the regulatory rigidity of the EU spectrum governance system, root cause of the ineffective flexibility in adaptation to the fast-paced digital economy. As we know by now, the EU consensus-driven governance model, although effective in securing inclusivity and long-term political stability, lacks the flexibility necessary to support transforming capabilities.

In the attempt of developing increased regulatory flexibility, our policy recommendation aims at streamlining regulatory processes through enhanced authority of the BEREC and partial reshaping of the governance system. More in detail, we argue that a potential solution could be to grant BEREC with the necessary authority to introduce amendments in the regulations of the spectrum without the requirement of unanimity of all Member States. A possible option would be to allow for a supermajority of Member States to trigger a "fast-track" amendment process without the mandatory requirement of unanimity, potentially moving toward a more streamlined centralized approach as that of the USA.

To conclude, our EU-USA cross-country comparative analysis of spectrum management approach has highlighted a limited number of key areas where the EU can improve its seizing and transforming capabilities. We argue that the EU can improve its capability in reaping the benefits of cutting-edge digital technology and secure competitiveness by harmonizing spectrum assignment processes, embracing spectrum-sharing models, enhancing public-private partnerships, and streamlining regulatory processes. The policy recommendations here outlined are backed by qualitative insights from experts and quantitative elements collected in reports as the DESI and GSMA's. This forward-looking section has offered a roadmap for improving the EU's seizing and transforming capabilities in spectrum management and strengthening its competitiveness in the digital age.

Chapter 6: Future-Proofing EU Spectrum Policy: Lessons and Pathways

6.1 Introduction: Synthesizing Key Findings

This final chapter aims at outlining the key findings and insights of our analysis, meanwhile setting the direction for strategic improvement in EU spectrum management. This concluding section, provides a summary of what has been discussed in the previous chapters, putting together the analysis' findings on the role of EU sensing, seizing and transforming capabilities in safeguarding long-term competitiveness through effective spectrum management.

The ultimate objective of the thesis was to assess, through the lenses of Dynamic Capabilities Theory, the effectiveness of the EU spectrum management in promoting competitiveness. This theoretical approach has led us to the conclusions that the EU spectrum governance, despite being successful at sensing incoming technological trends and market demand through a proactive approach, it struggles in seizing and transforming due to fragmented policy implementation and slow regulatory adaptation. These elements altogether have caused delays in new technological adoption, as in the case of 5G, negatively impacting the technological gap vis a vis major global competitor like the USA and China.

The EU-USA comparative cross-national analysis has identified key differences in spectrum management approach. On the one side, the EU is characterized by a decentralized, consensus-driven approach, while the USA by a market-driven philosophy with stronger centralized management under the supervision of the FCC. We have assessed that the FCC's streamlined management demonstrates a notable level of regulatory flexibility and quicker adaptation to innovative models of spectrum use, like those of spectrum-sharing models in the Citizens Broadband Radio Service (CBRS). These combined elements enable the USA to efficiently reap the benefits of a well-executed spectrum management.

6.2 Sensing Capabilities: Successful Strategic Foresight with Ineffective Execution

The EU has showcased strong sensing capabilities by early detecting and designing comprehensive strategies to tackle and facilitate the emergence of new technologies. For instance, EU-led initiatives like the 5G Action Plan and the Digital Single Market Strategy display the ability in proactively foresight and early detecting technological trends and their potential impact. For instance, the 5G Action Plan has set in 2016 ambitious goals in terms of 5G coverage across the Union, acknowledging the critical role of 5G networks for innovation and GDP growth in the incoming years, sign of a successful sensing activity (European Commission, 2016).

However, there is a marked difference in effectiveness when it comes to translating strategy into actions. In fact, sensing capabilities have not been matched by equally effective capabilities in seizing the opportunities deriving from technological innovation. The fragmented regulatory landscape of the Union has provoked delays in spectrum auctions, disparities in urban-rural broadband availability and uneven 5G rollout across regions. The difficult progress in achieving the 5G objectives is reflected in the DESI 2023 and Ericsson Mobility Report 2023, which show that the only 66% of EU population has access to 5G, while in the USA enjoys a much higher rate of 95% (Ericsson Mobility Report, 2023; DESI, 2023).

6.3 Seizing Capabilities: Delays in Spectrum Assignment and Lack of Harmonization

The analysis of seizing capabilities furnishes us with a markedly more negative assessment of the effectiveness of EU spectrum management. In this case, bureaucratical and structural barriers have hindered the EU ability to capture opportunities and avoid challenges in spectrum management. This inability is often deriving by the high level of national autonomy over assignment processes, which tends to favour national interests over broader EU-wide policy goals. This approach has led to too often delayed and uncoordinated spectrum auctions across borders, all elements inhibiting the international dimension of spectrum-based technological applications. Such barriers reduce the attractiveness of the Single Market to private investments, depriving the Union with the amount of capital necessary to ensure strong and

resilient digital infrastructures. Moreover, our research has unveiled a systemic EU weakness in effectively collaborating with private actors through PPPs. EU initiatives like the Connecting Europe Facility (CEF) and European Structural and Investment Funds (ESIF), proved to be successful in strengthening digital infrastructures, however they majorly focus on financing public investments, with little utilization of PPPs for attracting private capital. Contrarily, the USA has launched initiatives like the Infrastructure Investment and Jobs Act (IIJA) and the Rural Digital Opportunity Fund (RDOF), which proved to be effective in supporting private investments, especially in underserved areas, leading to a smaller urban-rural digital divide (+15%) if compared to the EU (+24%) (FCC, 2023; DESI, 2023).

6.4 Transforming Capabilities: Limited Flexibility and Slow Regulatory Adaptation

The transforming capabilities of the EU, which enable adaptation and reconfiguration of resources according to the changing conditions, encounter similar challenges of fragmentation and rigidity. The EU consensus-driven governance, while being effective in safeguarding long—term political stability, it however lacks the agility necessary to rapidly reshape its structure according to shifting market demands. On the contrary, the FCC centralized governance system permits a faster adaptation to changing conditions, as for the case of the introduction of innovative solutions such as spectrum-sharing methods. In this case, the EU has proven not to be effective in rapidly embracing and implementing these innovative, more efficient, modalities of spectrum use.

This stiffness in regulatory adaptation has hindered EU's organizational learning, despite the existence of valuable platforms for knowledge exchange as the RSPG. In addition, there is a structural imbalance in stakeholder engagement participation, with larger established telecom players exerting a disproportionally stronger influence compared to smaller market entrants. The lacking inclusion of SMEs and start-ups has deprived the EU consultation process of innovative inputs, typical of new rising market players.

6.5 Policy Recommendations: Enhancing the EU's Seizing and Transforming Capabilities

Ultimately, the findings of our research have led us to the formulation of policy recommendations aiming at addressing the EU's seizing and transforming capabilities and to positively influencing the EU competitiveness in the global digital economy. These proposals focused on the previously detected flows of EU spectrum management, specifically aiming at improving regulatory flexibility, harmonization, and investment in digital infrastructure.

6.6 Harmonizing Spectrum Assignment Processes Across the EU

Our first policy recommendation aims at addressing the lack of harmonization by strengthening the role of the Body of European Regulators for Electronic Communications (BEREC). We argue that it is necessary to enhance the authority of the BEREC in supervising and coordinating the "when" (timelines) and "how" (regulatory procedures) of spectrum auctions. This strengthening in authority would support coordination of auctions, leading to lowered inefficiencies and delays. Moreover, the newly acquired authority, would favour an increased alignment between national interests and the EU-wide goals envisaged in the EECC, ensuring a timely and efficient spectrum assignment.

Additionally, we suggest the Commission to leverage existing funding mechanisms to incentivize efficiency in assignment. More specifically, we propose to envisage in the CEF and ESIF an ad hoc financial bonus linked to timely and coordinated spectrum auctions. This tool would encourage Member States to align national priorities with boarder EU-wide goals, enhancing the effectiveness of seizing capabilities through spectrum assignment.

6.7 Adopting Spectrum-Sharing Models for Increased Efficiency

Our second policy recommendation aims at increasing efficiency in spectrum usage by encouraging the EU to explore the adoption of spectrum-sharing models, following the example of USA's CBRS system. This approach allows multiple users to simultaneously access the band, increasing the efficiency of use. This result would be key for accommodating the growing spectrum demand driven by the adoption of new technologies such as and IoT and AI.

In line with our first recommendation, even in this case we argue that the BEREC should be strengthened with increased authority in supervising the deployment of this new approach. This element would ensure new markets entrants and smaller operators with fair access to the bands, following the best practice of the General Authorized Access tier of the CBRS.

6.8 Enhancing Public-Private Partnerships (PPPs) for Digital Infrastructure Investment

Over the course of our enquiry, we extensively underlined the critical role played by PPPs in reducing digital divide by supporting infrastructure investments, especially in underserved rural areas. Based on this, we encourage the Commission to foster PPPs by establishing an "EU Digital Infrastructure Investment Fund" to incentivize private companies in investing in underserved regions. The Fund's resources would increase the attractiveness of areas with poor digital infrastructures, traditionally characterized by low return on investment. In turn, this approach would contribute to shrinking the digital divide, critical element in the safeguard of a cohesive Union.

Even in this case, the USA provides us with a best practice which could be emulated. The USA's Rural Digital Opportunity Fund (RDOF) has successfully leveraged private investments to reduce the urban-rural disparity in broadband availability. Similarly, by deploying the "EU Digital Infrastructure Investment Fund", the EU could enhance 5G deployment and boost its digital infrastructure competitiveness.

6.9 Streamlining Regulatory Processes for Faster Adaptation

Lastly, our final recommendation aims at tackling the EU lack of flexibility in regulatory processes. We argue that the introduction of a supermajority-based fast-track amendment procedure for spectrum regulation would help in streamlining the spectrum regulatory governance, reducing bureaucratic rigidity. This approach would diminish the dependency on unanimous consent among Member States, consequently supporting quicker regulatory adaptation to technological changes.

Even in this case, we argue that a BEREC's increased authority in overseeing and implementing amendments, would be instrumental in keeping pace with the rapid shifts of market demands for spectrum.

6.10 Concluding Remarks: The Future of EU Spectrum Management

In conclusion, the results of our research have clearly showcased the direct link between spectrum management and EU digital competitiveness. While the EU has proved notable strengths in early sensing emerging technological trend, it still showcases significant weaknesses in seizing opportunities and transforming internal mechanisms to support its digital competitiveness.

The overall analysis has contributed to a deeper understanding of the application of Dynamic Capabilities Theory in the field of public policies, leading us to the formulation of actionable policy recommendations for EU policymakers. The findings and insights of our research have given substance to policy proposals aiming at improving the EU effectiveness in sensing and seizing. These recommendations range from enhanced harmonization and spectrum-sharing to improved public-private partnerships and streamlined regulatory processes, all key elements in the development of dynamic capabilities to strengthen the EU global position in the digital economy.

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