Quantum Technology and its influence in Global Power Politics

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ABSTRACT

The interpretation of technology as a form of power in global politics has played a crucial role in the shaping of the structure of the international system throughout history. Despite the relevance of technology in power politics, relatively little systematic attention has been given to the role of new and emerging technologies, especially in terms of the influence of their spread and effects on the dynamics of the international system and the strategic balance of power. This dissertation studies the influence of Quantum Technology (QT) in global power politics. It empirically explores and evaluates the relationship between QTs and three major global powers: China, the United States, and the European Union, in order to assess how future trajectories in this technology can influence the dynamics of the international system and the strategic balance of power.

Building on a theory on military innovation and technological change, i.e. Horowitz's Adoption-Capacity (AC) theory, the study focuses on deepening the understanding of the spread of QTs by analysing the incentives and constraints behind major global power's decision to adopt and develop such technology. Furthermore, it evaluates the implications of this technology for the balance of power, the structure of international competition, and future warfare. The study adopted a mixed methods approach and combined document and discourse analysis to investigate these issues. The analytical procedure mainly entailed finding, selecting, appraising, and coding data contained in different data sources, namely those country quantum-related strategies and initiatives, as well as speeches and press releases from top government officials.

The findings demonstrated that national pride, geostrategic competition, and dimensions of national and military power, as well as implicit assumptions of threats and quantum capabilities are influencing major global powers to adopt and develop QTs.

State behaviour is also pushing for the rapid advancements in this technology, as a result of pressure from actors to improve and translate quantum capabilities into a new form a power. In the advent of new and emerging technologies, QTs demonstrate a unique potential to influence the dynamics of the international system, the strategic balance of power, and future warfare. Not only was it revealed that QTs can transform current paradigms of military power, with significant implications for the future of military communications, encryption, and stealth technologies; but they can also reset the military and intelligence balance in China's favour. Moreover, QT's commercial applications may set some changes in the economic arena, where first movers that innovate and generate new ways of producing forms of power in QT can gain significant advantages and sustain their global leadership in this quantum revolution. Nevertheless, as this technology reaches maturity, the impacts and consequences of QTs will not be determined in months or years, but rather in the decades to come. Most importantly, it will eventually be determined by how countries themselves end up using these technologies in practice, and how they react and determine their future trajectories in QTs.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Adoption-Capacity Theory
CAQDAS	Computer-assisted Qualitative Data Analysis Software
CMB	Code Matrix Browser
DARPA	Defence Advanced Research Projects Agency
EU	European Union
FYP	Five-Year Plan
ICT	Information Communication Technologies
IQM	Interactive Quote Matrix
IR	International Relations
ISR	Intelligence, Surveillance and Reconnaissance
ISS	International Security Studies
MIC	Made in China
NIST	National Institute of Standards and Technology
NQIA	National Quantum Initiative Act
NSA	National Security Agency
NSF	National Science Foundation
NSOQIS	National Strategic Overview of Quantum Information Science
ODB	Offense-Defence Balance Theory
PLA	Chinese People's Liberation Army
QCI	Quantum Communication Infrastructure
QFI	Quantum Flagship
QIS	Quantum Information Science
QKD	Quantum Key Distribution
QM	Quantum Manifesto
QT	Quantum Technology
R&D	Research and Development
S&T	Science and Technology
SCOT	Social Construction of Technology
SRA	Strategic Research Agenda
SSK	Sociology of Scientific Knowledge
STS	Science and Technology Studies
US	United States

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CHAPTER 1: INTRODUCTION

Throughout history, technological innovations have transformed global politics significantly. Understood as either a causal variable or as a background context, technological innovations have been recognised, both theoretically and empirically, as an important factor influencing state-actors' decisions and their subsequent outcomes (Archibugi & Michie, 1997; Rosenau & Singh, 2001; McCarthy, 2018). From a macroscopic viewpoint, technology has been considered as an axis of power for nation-states by aiding in the facilitation and maintenance of national security, territorial integrity, autonomy, sovereignty, and national economic development (Grübler, 1998; Keohane & Nye, 1998; Lele, 2019). However, from the same standpoint, technology has entailed 'who is empowered versus disempowered; who is constrained in a given situation versus who gets to write the rules; and, finally, how basic identities, interests, and issues themselves are reconstituted or transformed in particular historical contexts', in turn redefining other relations of power and technology (Rosenau & Singh, 2001, p. 6).

Despite the relevance of technology in power politics, there has been relatively little systematic attention in the academic literature to the role of new and emerging technologies in global politics, particularly in terms of the influence of their spread and effects on the dynamics of the international system and the strategic balance of power. In an effort to fill in the gap, the dissertation proposes to assess the issues Quantum Technology (QT) raise for the traditional balance of power and international competition through the lens of academic research on military innovation, technological change, and global politics. QT, although with no universal agreement on definition, is defined in this study as: *a world-class technology that uses individual quantum states and properties of* *quantum mechanics, namely quantum entanglement, quantum superposition, and quantum teleportation.* With these properties, QTs are expected to provide far more powerful instruments than any other technology.

QT has demonstrated to be one of the most significant technological innovations of the 21st century, with impressive revolutionary power in a wide range of applications that were initially unthinkable (Kania & Costello, 2018; López, 2019). The employment of quantum cryptography can create quantum communications systems that are theoretically unbreakable and unhackable; quantum computation can outperform classical and supercomputers on computational power and problem solving; and quantum sensing can enable the capability to conduct extremely precise, accurate measurements for new forms of navigation, radar, and optical detection (Costello, 2017; López, 2019; Verhagen, et al., 2019). As QTs are expected to disrupt current technology used in almost every sector and industry, generating perhaps the greatest social-political impact of our time, is thus crucial to understand its unique potential beyond the ‘quantum’ realm.

In particular, this dissertation aims to study the relationship between QTs and major global powers—namely China, the United States, and the European Union—to assess how the future trajectories in this technology can influence global power politics and the international system dynamics. Building on Horowitz’s Adoption-Capacity (AC) theory, the dissertation focuses on deepening the understanding of the spread of QTs, i.e. on the incentives and constraints behind major global power’s decision to adopt and develop such technologies, and most importantly, the implications that can influence the balance of power, the structure of international competition, and future warfare. As AC theory (2010, p. 2) posits, technological innovations alone rarely shape the balance of power, instead much of the potential impact of technological innovations—whether in commerce, military affairs, or strategic balance of power—depends on how governments and organisations make choices about the adoption and use of new technology than on the technologies themselves.

As a theoretical framework, AC theory guides the study indicating which variables and conditions this dissertation needs to appraise in order to make its own assessment on the adoption of QTs and future potential implications. The research question and main objectives for this dissertation are accordingly define as follows:

Research Question:

How advancements in quantum technology (QT) might influence power politics in the foreseeable future?

Research Objectives:

1. To determine which are the strategic ambitions of major global powers in QT and the extent to which these can impact the structure of balance of power
2. To assess what is the discourse, postures, behaviours and overall expectations of major global powers towards QT adoption

The study adopts a mixed methods approach and combines documentary and discourse analysis methods to investigate: (1) the causes that drive major global powers towards the adoption of QTs, and (2) the real meaning (reinforced by postures, behaviours, and expectations) major global powers have towards those technologies. This involved collecting data from a variety of sources, namely those key quantum-related strategies and initiatives, as well as speeches and press releases from top government officials. The analytical procedure thus mainly entailed finding, selecting, appraising, and coding data contained in various documents and spoken forms of communication. This was performed through a computer assisted qualitative data analysis software (CAQDAS) package, MAXQDA, that was used to organise excerpts, quotations, entire passages, and parts of speeches into themes for uncovering meanings and patterns of the research problem.

In the sum, the adopted theoretical framework, methods, and research methodology, intend to produce a rich insight into the relationship between major global powers and QT advancements by unveiling overt and covert incentives and constraints in their quest for adopting QTs. Furthermore, they aim to develop a deeper understanding on how major power's identities, cultural background, and sentiments are shaping current decision-making processes, behaviours, and expectations for harnessing QT. Overall, the expected outcome of this study is to contribute to the general discussion on the impact of new and emerging technologies on global politics and international security.

The structure for the following four chapters of this dissertation is as follows: Chapter 2 discusses the background literature and provides an overview on the conceptual place of technology in global politics and its dominant treatment as a form of power in International Relations (IR) and International Security Studies (ISS). It further examines existing theories of technology and explores those scholarly sources and other valuable material on the quantum field. Chapter 3 outlines the research methodology and methods applied for conducting this study. It addresses the role of theory and describes the research process of this study, including the process of collecting, displaying and interpreting the data gathered. Chapter 4 presents the findings and analysis of documentary and discursive evidence. It presents its own assessment on the adoption of QTs and potential implications for the balance of power, the structure of international competition, and future warfare. Lastly, Chapter 5 concludes the study and revisits the main findings. It presents some of the limitations in conducting this study and offers some suggestions for future research.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews existing literature on QT and global politics. Considering that this dissertation studies the relationship between QT and global power politics—a relationship whose intricacies and broad meanderings are yet to be understood by the academia and the different influencing actors and that much of its literature is based on presently ongoing projects and initiatives—it is necessary to return to the literature that discusses the relationship between technological innovations and global power politics.

Section 2.1 discusses the conceptual place of technology in global politics and its dominant treatment as a form of power in IR and ISS. Section 2.2 reviews three different theories that perhaps are the closest in the field to account for the effect of technology in global power dynamics and international security—the theories of Offense-Defence Balance(ODB), Adoption-Capacity (AC), and the Social Construction of Technology(SCOT). Lastly, Section 2.3 reviews those scholarly sources and valuable material on key debates, perspectives, developments, trends, and patterns in the quantum field, as they might provide a constructive vision of QT's real significance in power politics.

2.1 Technology, Global Politics, and Power

Technology has been central to the discipline of IR and ISS throughout its history (McCarthy, 2015). From the mid-twentieth century to modern days, scholarly efforts that deal with the relationship between technological innovations and global power politics have greatly expanded. The formal inception of the discipline emerged in the aftermath of the First World War, in which the destructive potential of modern military weaponry was thoroughly illustrated. The industrialisation of warfare and the application of the most advanced technological artefacts form the background for the varied literature that explains the role of technology in great power politics, the effects it has on the traditional balance of power, and the politics of technological artefacts.

Alfred Zimmern (1928)—holder of the world's first chair in International Politics created in 1919—placed his theorisation of the international within the context of rapid technological change. Similarly, Norman Angell (1914), Leonard Woolf (1916), E.H Carr (1939), among other prominent thinkers, stressed the significant role technology has in shaping international political life and geopolitical competition, for which at the time technology was not only considered a key driver towards 'greater integration' but a 'potential for conflict' (Osiander, 1998; McCarthy, 2018). The ongoing industrialisation, new military technologies, and the expanding reach of transport and communications technologies posed a profound challenge to existing forms of 'territorial state sovereignty', as argued by Carr (1939). A technology driven change reshaping the size and nature of political units was 'perhaps likely to be more decisive than any other for the course of world politics in the next few generations' (Carr, 1939, p. 230).

During the Second World War, and its aftermath, most central markers and figures in the modern analysis of technology further referred to the 'equation between technological innovations, modernity, scientific discovery, and instrumental rationality' (Sylvest, 2013, p. 123). They were mostly influenced by the disciplines' reaction to new technological developments in weaponry, rocketry, communications and advancements in intelligence; including but not limited to: biological, chemical and atomic weapons, ballistic missiles, automatic aircraft, and navigation and communication devices. With a new understanding of the disruptive effect of these new technological capabilities, the role of technology in 'traditional' structures of global politics—anarchy, sovereignty and inter-state competition—became a prominent topic to discuss in the academic literature, perhaps the most significant one.

With the common understanding that the balance of power is not stable but evolving because actors face a constant security dilemma—meaning that, due to uncertainty, actors live in constant fear—realist thinkers characterise the ultimate long-standing interest in the role of technology in power politics, where they considered the issues of survival, international (power) competition and dominance (Mearsheimer, 2001; Schmidt, 2005; Rosch & Lebow, 2018; Lele, 2019). For instance, under the realist perspective a nation-state ought to acquire material power—including developments and adoptions of different technologies—to become 'secure' in an anarchical world (Morgenthau, 1949; Craig & Valeriano, 2017). This perspective endorses nation-states to acquire the tools necessary for addressing their political, economic, and military and modernisation challenges, as well as for countering those rising traditional and non-traditional security issues (Lele, 2019). Consequently, advances in technology were no longer seen by central figures as a movement towards multilateralism or 'greater integration', but as an 'instrument, a threat, control of force, or form of power' (Algosaibi, 1965; Tripp, 2013). According to McCarthy (2015, p. 3), this stress on technology as one of the material resources that define power has, in many ways, defined our current understanding of technology in global politics and international security, to the extent that scholars arguing for alternative perspectives effectively cede this ground to a Realist understanding (Nye, 1990; Guzzini, 2005).

With the newly found capacity of humankind to destroy all life on earth by thermonuclear weapons during the Cold War, these notions of realism, its understanding of technology and influence in global power politics and international security were heightened by the nuclear arms race (Craig, 2003; Sylvest, 2013). Not only did it demonstrate that the interpretation of threats in the international system constantly changes according to new technological advancements and the real significance they have in terms of global politics and power for nation-states (Baldwin, 1993; Buzan, 1996; Morgenthau, 1978), but also that technological innovations may alter the historical condition of anarchy, pushing global politics towards the development of a new 'world state', where the precise shape of the impact of a technological innovation is dependent on the micro-politics of technological design, development, and adoption from individual states (Craig, 2003; Deudney, 2008; McCarthy, 2015; McCarthy, 2018).

Understood as either a causal variable or as a background context, technological innovation continues to be recognised in current times, both theoretically and empirically, as an important factor influencing actors' decisions and their subsequent outcomes (Archibugi & Michie, 1997; Rosenau & Singh, 2001; McCarthy, 2018). Not only has technology been considered as an axis of power for nation-states by aiding in the facilitation and maintenance of national security, territorial integrity, autonomy, sovereignty, and national economic development (Grübler, 1998; Keohane & Nye, 1998; Lele, 2019), but it has entailed 'who is empowered versus disempowered; who is constrained in a given situation versus who gets to write the rules; and, finally, how basic identities, interests, and issues themselves are reconstituted or transformed in particular historical contexts', in turn redefining other relations of power and technology (Rosenau & Singh, 2001, p. 6).

In most recent days, new technological trends require for the IR and ISS field to engage with new theories, trends, and patterns that discuss the significant potential and effect of new and emerging technologies in power politics. Under different philosophical perspectives, scholars make efforts to analyse the importance in analysing how power can shift by the adoption and use of different technologies. For QT, however, policy papers and scholarly sources are still limited in providing a full understanding of how it could transform the economic, military, and security realms, or the overall international system dynamics. For this reason, in the following section this dissertation reviews key theoretical accounts which explain how technologies are adopted and how they shape global politics

2.2 Theories of Technology

Technology and innovation theories date back to ancient Greek philosophy and started with Plato and Aristotle separating skill, wisdom and knowledge into the 'Techne' and 'Episteme' (Lele, 2019, p. 11). Ever since, our understanding of science and technology has been shaped thanks to multidisciplinary approaches embraced by different schools of thought that have implemented methodological, theoretical, and sociological approaches to explain the intricate nexus between technological innovations and its resultant impact. Emerging from the Sociology of Scientific Knowledge (SSK), the history of science and post-positivist philosophy (Kuhn, 1962; Berger & Luckmann, 1967; Bloor, 1976), interest in the social shaping of technology has resulted in the creation of a distinct sub-field of sociology, known as Science and Technology Studies (STS), which arranges professional associations, journals, and disciplinary debates of its very own (McCarthy, 2018, p. 2). STS has become one of the most theoretically dynamic and empirically productive fields in the social sciences, mostly influential in IR and ISS (McCarthy, 2018). These theories range from the traditional analytical philosophies of Technological Determinism (Bimber, 1990), Social Construction of Technology (Pinch & Bijker, 1984), Diffusion of Innovation Theory (Rogers, 1983), to Offense-Defence Balance Theory (Jervis, 1978; Lieber, 2000) and newer ones such as Adoption-Capacity Theory (Horowitz, 2010).

However, as many STS scholars express: technology remains the unopened 'black box' that could be used in explanation but was never itself explained—a *deus ex machina*, as it were (McCarthy, 2018, p. 5). A generic issue with existing theories of technology is that these theories often treat technology as an 'afterthought or residual variable' rather than intertwined with politics, as argued by Herrera (2007, p. 193). Geopolitical competition and the presence of multiple political communities are often not theorized in the classic STS analyses (McCarthy, 2018). This conception is prevalent among other scholars, such as Craig and Valeriano (2017), who argue that with the exception of Offense–Defence Balance theory, which includes technology as one of a number of independent variables, 'there is little overarching theory or understanding of how technology spreads through the international system, its relationship to state power, or its consequences for international security' (p. 1).

Despite the relevance of technology in power politics, there is relatively little systematic attention in the academic literature to the role of emerging technologies—including that of QT—and its influence in the dynamics of the international system and battlefield. Much progress needs to be done in providing a more detailed and accurate understanding on how global political conduct creates, and is created by, the politics of technological artefacts; how new technologies are shaping power holder's ideas, organisation, and their overall behaviour; and more specifically, how they are reconfiguring, constituting, or reconstituting power holder's identities and interests.

Nevertheless, one cannot disregard the fact that certain STS theories provide valuable insights on the relationship between technology and global politics, the development and diffusion of technological artefacts and systems. STS theories have improved considerably the understanding of the socio-technical empirically, but crucially, also how these theories can help young scholars rethink key concepts in IR, such as power, anarchy, sovereignty, agency, structure, and international system dynamics (McCarthy, 2018, p. 16). This section, consequently, reviews three different theories that perhaps are the closest in the field to account for the effect of technology in global power dynamics and international security—the theories of Offense-Defence Balance(ODB), Adoption-Capacity (AC), and the Social Construction of Technology(SCOT).

In the academic literature, the offense-defence balance is often considered a key determinant in deciding whether the international system as a whole is more violent or more stable, and whether individual states act aggressively or defensively (Jervis, 1978; Levy, 1984; Lieber, 2000; Glaser, 2010). This theory is widely used to explain the likelihood of war, and other destabilizing phenomena such as arms races, conventional and nuclear deterrence, as well as the so-called revolution in military affairs. With the birth of information communications technologies (ICTs) and other emerging technologies, the ODB theory has similarly been used as a framework to explain the intense security competition among states and its consequent in the structure of the international system (Lieber, 2000).

From a realist perspective, the ODB theory has determined that threats are more important than raw material power in explaining state behaviour (Glaser & Kaufmann, 1998). It has provided a systematic method of predicting when technologies will favour the offence or defence, and how this could potentially threaten the balance of power, as argued by Glaser (1994). While a technological innovation might strengthen the defence relative to the offence, states are more likely to feel secure and act benignly (Jervis, 1978). However, a shift in balance towards offence is the primary reason for the pre-existing races among nations in earlier years (e.g. space race and nuclear arms race) (Lieber, 2000).

As ODB variables remain closely interlaced, scholars argue that certain advancements in technology made in the civilian and commercial domains might end up influencing the development of military innovations, making the distinction between the two increasingly difficult to grasp given the rapid pace of technological advancement and proliferation (Lele, 2019). Similarly, ODB has come under intense criticism for, among other things, the categorisation of certain technologies as either offensive or defensive, its immeasurability, and its lack of parsimony (Davis, et al., 1998). It also makes little or no reference to the importance of other variables such as diffusion, power, and skill (Lynn-Jones, 1995).

If QTs are still in their infancy and scholars remain unsure as to whether quantum advancements would favour the offence or defence (International Institute for Strategic Studies, 2019)—and what effects these can have on the traditional structure of balance of power—it becomes more practical for this dissertation to build on a theoretical framework that reflects upon other key variables that help further explain: (1) why states acquire these new technological innovations; (2) what new possible capabilities these technology might generate (e.g. quantum offence and/or quantum defence) and; (3) how these might influence future warfare and international competition. As we are still in the advent of a quantum race, this dissertation will thus utilise two additional theories to gain a more comprehensive understanding of the development, diffusion, and implications of technological innovations, rather than simply studying the empirical evaluation of how technological artefacts can be conceptualised or categorised to explain the onset or absence of a race or 'war'.

Horowitz's Adoption-Capacity theory (AC) moves away from those classical theories and goes deeper into explaining the ways in which states respond to new technological innovations, especially those that have military implications. According to Horowitz, 'most assessments of the international security environment fail to incorporate either the relevance of technological innovations or the importance of their spread'; hence AC theory focuses on expanding the understanding of 'the spread of technological innovations throughout the international system' and 'how variations in the diffusion of new innovations influence international politics, especially the balance of power and warfare' (Horowitz, 2010; Chavez, 2014).

Inspired by the scholarship on military innovation by Barry Posen (1984), Stephen P. Rosen (1991), and Dima Adamsky (2010), AC theory heightens the common understanding that technological innovations alone rarely shape the balance of power. Instead, it is how states employ a technology that makes a difference. In particular, AC theory posits that the impact of technological change on global politics—whether it is change in economy, society, diplomacy, or military power—depends much more on how governments and organisations make choices about the adoption and use of new technology than on the technologies themselves (Horowitz, 2010). For instance, this theory explores the conditions under which major and emerging powers are most likely to develop and adopt new technologies, as well as the effects these account for—that is not only how innovations diffuse; how states respond to innovations; but also how those patterns impact international politics (Horowitz, 2010, pp. 11-21).

Nation-states have a number of possible strategic choices in the face of new technological innovation, including adoption, offsetting or countering, forming alliances, and shifting towards neutrality (Horowitz, 2010, p. 5). Horowitz's AC theory focuses on the adoption-capacity requirements of an innovation and how the capacities of individual states measure up. In particular, it theorises that 'for any given innovation, financial resources and organisational changes required for adoption govern the system-level distribution of responses and influence the choice of individual states' (Horowitz, 2010, p. 5). In other words, the adoption requirements of a given innovation, and state's capacity to meet such requirements, influence modern decision-making of individual states towards new technology and drives its effect on international system dynamics. This is important because countries are now more compelled than ever to push their financial capital and make all organisational changes needed to successfully adopt and exploit emerging technologies. Therefore, this theory may prove useful to understand current decision-making and behaviour of individual states towards the adoption of QTs by further elaborating on the significance of countries' financial resources and organisational changes for succeeding in the mastery of QTs.

As AC theory is more of a 'decision theoretic' approach, it can also be useful for understanding the broader debate on how strategic competition, domestic politics or international norms influence state behaviour towards the adoption of new technologies. In particular, this theory suggests that nation-states are influenced by a series of incentives and constraints that shape its eventual response strategy. For example, Horowitz refers to the geostrategic environment as one of the most significant factors determining the range of states interested in an innovation (2010, p. 25). Nonetheless, he also gives special consideration to other factors that determine why states are interested in the adoption of new innovations, ranging from necessity to international norms, cultural or national pride to the need for interoperability with allies, as well as implicit assumptions about capabilities and threats, among other variables (Horowitz, 2010, pp. 9-25).

At the system level, AC theory predictions are based on the requirements for adopting an innovation and assumptions about the distribution of capabilities in the international system. It explains both why some shifts in relative power occur and how. As Horowitz (2010) expounds, some new major technological innovations constitute disruption in international politics that can generate larger power disparities:

> First movers that innovate and generate new ways of producing forms of power can gain significant advantages; the exploitation of these advantages then can usher in power transitions, exposing status quo powers that can become overmatched paper tigers […] rising powers that become first movers are especially likely to experience

> large gains in relative power […] first-moving existing powers that can rapidly emulate or otherwise adapt to an innovation can make relative power gains, or help stave off disadvantageous power shifts (pp. 42-44).

This indicate to some extent that innovations more generally trigger strategic responses on the rest of the international system, with success and failure in the world of the new innovation determined by the potential for generating new capabilities and strategic postures (Horowitz, 2010, p. 28). While over time all these things vary, in the short-term, according to Horowitz, they are invariant enough to allow for stable predictions. Thus, based on a range of possible choices, the AC theory derives the most probable outcomes for individual states given their capabilities, the requirements for adopting the innovation, and the configuration of the international system (Horowitz, 2010, p. 30). These are crucial aspects to consider when analysing the relationship between major global powers and QTs.

Although AC theory is not a very well-known theory and often lacks the attention it deserves, it provides valuable insight in explaining why technological innovations depend on how nation-states adopt and utilise technologies, rather than on the raw characteristics of the technology *per se*. Besides providing a different perspective and being more malleable for studying the role of emerging technologies in the international security environment and global politics, this theory offers greater leverage than existing approaches for understanding current decision-making and behaviour of individual states towards the adoption of QTs. Most significantly, for this dissertation AC theory can allow to easily determine which are the incentives and constraints that are shaping major global powers' response strategy for adopting QTs, and how these can influence the balance of power and the structure of international competition in the near future.

Another theory that perhaps is the closest in illuminating to what the degree technological advancements—bearing a set of values and interests—cause different actors to behave in certain ways is the Social Construction of Technology (SCOT) theory. In contrast to other theories, including those notions of technological determinism, SCOT leading adherents Trevor Pinch and Wiebe Bijker argue that, in order to understand how technology is created, one has to break down the division between the social and the technical—as technology by itself does not determine human action, but that rather human action shapes technology (Bijker, et al., 1987).

In 1992, Alexander Wendt famously stated that 'anarchy is what states make of it' in relation to the state system (Wendt, 1992; Wendt, 1999). Outlining the constructivist school of IR he asserted that the structures of the international system were not so much permanent and unchanging as they were 'socially created and dynamic- (Manjikian, 2018, p. 25). Wendt stated that politicians and experts both had the ability to 'do things with words', in essence using language to create particular state identities, norms, and understandings of how the world works, thereby establishing friendships, rivalries and alliances which could be both done and undone through the power of language (Manjikian, 2018, p. 26). Wendt's intervention prompted a sustained debate in IR and STS as to whether material factors or ideas, interests, or identities were the central motivating causal force in international politics.

Advocates of SCOT—that is, social constructivists—cede to these notions, claiming that the ways a technology is used cannot be understood without understanding how that technology is embedded in its social context (Klein & Kleinman, 2002). Therefore, this theory is considered an agency-centred approach that suggests that multiple groups—whose actions manifest the meanings they impart to technological artefacts—can influence how society defines and implements a technology (Klein & Kleinman, 2002). While designers, engineers, and scientists physically construct or create an object, interest groups (e.g. state actors) also construct the object by virtue of the language they use to describe the object; the ways in which technology is 'marketed and sold' to societies; and the ways in which it is regulated and understood. A technology's meaning 'cannot be understood apart from the language or discourse which exists to describe it' (Manjikian, 2018, p. 26).

Just as Horowitz' AC theory considers the incentives and constraints that shape major powers' eventual response strategy, the SCOT framework reflects on the pre-existing parameters and limitations which help shape technologies. Nonetheless, when comparing both frameworks, SCOT only provides a mid-range answer to the question on how the shaping of technology can influence global politics. SCOT falls between social determinism (which says that society decides what a technology means) and technological determinism (Herrera, 2007, pp. 32-34) by stressing that both elements are central to the development of socio-technical systems at different moments in time, due to both 'technical' and social factors (Manjikian, 2018). Horowitz's AC theory, on the other hand, might provide a better answer on how countries are adopting certain technologies; how strategic competition, domestic politics, or international system dynamics influence current state behaviour towards the adoption of new technologies, such as QTs, and most importantly, why. Considering that this dissertation focuses on examining how QT advancements influence global power politics, AC theory thus seems to be a more a suitable theoretical framework to adopt for conducting this study. As a philosophical underpinning for mixed methods studies, this theory will shape the types of questions asked, inform how data is to be collected and analysed, and guide all aspects of conducting the study—this is later defined in detail under Section 3.2.

2.3 Quantum Implications in Global Power Politics and International Security

Previous literature indicate that technological innovations can indeed change the shape of global politics. Although some theories aim to establish a deeper understanding and interpretation of the distinct role of technology in either the social, political or technical spheres, all theories ultimately converge on the notion that technological advancements possess a disruptive potential to significantly transform the modern world, regardless of its nature. Nonetheless, QT studies still remain quite limited for providing understanding and explaining its disruptive potential on the global scale.

QTs are becoming one of the most significant technologies of the 21st century, with impressive breakthroughs across a range of industries and sectors, including medicine, economy, meteorology, energy, and military (Verhagen, et al., 2019). According to the Hudson Institute and others renowned research institutes, global supremacy will belong to the nation that controls the future of information technology (IT)—at the heart of which will be QT (Herman & Fiedson, 2018, p. 3; López, 2019). Nevertheless, scholarly sources and public policy papers indicate that QT advancements are expected to not only create significant opportunities for nation-states (Mavroeidis, et al., 2018; Hughes & Nordholt, 2017; Benedictis, 2019; O'Connor, et al., 2018), but also generate increasingly complex, ambiguous, and destabilising threats, catalysing profound societal, economic, and political shifts (Figliola, 2018; Herman & Friedson, 2018; Turner, 2010; Brassard, et al., 2000; Verhagen, et al., 2019; Campagna, et al., 2015; López, 2019). To date, major global powers and the most prominent technology firms are investing heavily in understanding, developing, and implementing these new technologies (López, 2019, p. 5). But what is quantum? And why are nation-states so interested in advancing such a futuristic-sounding field?

In the early 20th century, the study of an elusive physical phenomena gave a way to a new scientific theory: Quantum Mechanics (López, 2019). In the broader scope, quantum mechanics explains the behaviour of matter and its interactions with energy on the scale of atoms and sub-atomic particles that work in an utterly counter-intuitive way, which allow us to observe and measure processes that do not only take place in the microscopic world (López, 2019; Jaeger, 2018). The understanding of quantum mechanics was accelerated only with the so-called first quantum revolution (often referred as Quantum 1.0), which saw the overall creation of the field of quantum physics (European Commission, 2016). With prominent physicists discussing the basics of quantum theory at the Solvay International Conference on Electrons and Photons, the foundation for today's quantum mechanics was laid (Vermaas, et al., 2019). Amongst its founders were Nobel Prize winners Albert Einstein, Marie Curie, Max Planck, and Niels Bohr. Ever since, advances in Quantum Information Science (QIS) have evolved greatly allowing us to better understand quantum theory and develop hard and soft technologies at various levels of maturity (Verhagen, et al., 2019). For instance, it led to the development of the first ground-breaking technologies, ranging from transistors to lasers, without which current computers, mobile phones, and the Internet would be unthinkable (Demarie & Munro, 2018). Similarly, it led to the development of modern medical apparatuses to GPS, and even nuclear energy (Demarie & Munro, 2018; Vermaas, et al., 2019; Pritchard & Till, 2014; Europa Nu, 2018).

The most overpowering effects of quantum mechanics, however, are coming along with the second quantum revolution (often referred as Quantum 2.0). With quantum theory and QIS now fully established, Quantum 2.0 is now underway, improving our ability to use, detect, and manipulate previously unexploited quantum effects in customised systems and materials, adding a new stage to the already staggering impact of conventional information and communication technologies (European Commission, 2016, p. 5).This is increasingly relevant since Quantum 2.0 exploits a novel conceptual platform within which a family of next-generation disruptive technologies—that actively create, manipulate, and read out quantum states of matter—can be conceived, developed, and commercialized (Jaeger, 2018; Pritchard & Till, 2014). For this dissertation, QT has thus been defined as a world-class technology that uses individual quantum states and properties of quantum mechanics—namely quantum entanglement, quantum superposition, and quantum teleportation—to provide far more powerful instruments than any other technology (Kania & Costello, 2018; Vermaas, et al., 2019; Jaeger, 2018). Such strange and 'spooky' properties give these technologies unique power and potential to the extent that they are gaining relevance outside the realm of physics and mathematics, as they bring forth four highly disruptive variations of technologies that can cause an inevitable impact on the technical, political, and social levels:

(1) Quantum Computation

Quantum computing represents a sweeping technological breakthrough that is among the most far-reaching and challenging of QTs (Vernacchia, 2019; European Commission, 2016). To non-mathematicians, quantum computing is best explained in relation to the traditional computing that it is use today. Vernacchia (2019) expounds that while traditional computing can only consider values that are either 1 or 0, black or white, true or false, quantum computers can cope with infinite number of combinations and consider all options at the same time (p. 11). Thanks to its potential and power in problem solving and prediction, quantum computers are thus expected to exceed anything seen in computation so far.

As the European Commission (2020, p. 39) indicate, ‘the ability to process data fast will be a key driver for the future economy, where even marginal technological differences lead to valuable competitive advantages’. Governments and technology enterprises across the globe are accordingly working hard to make quantum computers a reality. More specifically, they intent to achieve a quantum advantage—also referred to as ‘quantum supremacy’—which is a state when quantum computers would perform tasks and solve problems that today’s most powerful conventional supercomputers cannot (or for them to perform is not economically viable) (Vermaas, et al., 2019; International Institute for Strategic Studies, 2019). With these new developments, therefore, the question governments are asking is not whether there will be quantum computers in the future, but *who* will be the first one to harness completely quantum supremacy.

However, this same technology poses some key challenges, particularly as regards to national security and geopolitical considerations. Amongst the latest threats and issues discussed in the literature are instances of machines being hijacked for their computing power to mine cryptocurrencies; election rigging; cyber physical attacks (e.g. attacks on power grids or aircrafts); encryption cracking or take-over of artificial intelligence tools—on top of increasingly sophisticated and devastating ransomware attacks and breaches of confidential and sensitive data (Herman & Fiedson, 2018; Vernacchia, 2019).

(2) Quantum Communication

Communication security is of strategic importance to people, enterprises, and governments alike; at present, it is provided by encryption via classical computers that could be broken by a quantum computer (European Commission, 2016, p. 10). Quantum communication hence involves a new generation of resources to use quantum states for producing secure communication protocols. It encapsulates new forms of both terrestrial and satellite secure communications to response to the threat from quantum computers and from algorithms capable of compromising classical encryption techniques (Acín, et al., 2018).

While quantum computing is still under development, some quantum communications are already in use: Quantum Key Distribution (QKD) across nodes connected by fibre and ‘free space’ quantum communications (i.e. over open air) (Kania & Costello, 2018; López, 2019). On the one hand, QKD provides ‘unbreakable information in transit’ security that, theoretically and in accordance with the ‘no cloning’ theorem, quantum information cannot be copied and any attempted interference or eavesdropping within a quantum system can be readily detected (Inglesant, et al., 2018). QKD hence ensures ‘perfect,’ or rather ‘provable’ security, including against future quantum computers which will have the power to break prevalent types of classical encryption (Auburn, 2003).

On the other hand, with free space quantum communications, new technologies such as long-term secure storage, cloud computing, and ‘quantum web’ or ‘internet’ are being implemented. Altogether, they can offer enormous benefits for governments, non-governmental organisations and corporations who want to solve computational challenges that are highly sensitive from a political or commercial perspective (Vermaas, et al., 2019). Nevertheless, they also pose new threats in the security landscape: opponents can use quantum communications to break (classical) encryption or develop new weaponry, as assessed by Acín et al. (2018). To date, concerns over quantum communications have thus been a major impetus for national security and defence investments in the field (Campagna, et al., 2015). Once employed at large scale, the resulting advancements of quantum communications could establish new paradigms in just about every context in which information is used, stored, collected, or processed, providing vastly more powerful instruments for security, computation, and measurement (Biercuk & Fontaine, 2017).

(3) Quantum Simulation

The design of aircraft, buildings, cars, and many other complex objects currently makes use of supercomputers (European Commission, 2016, p. 12). Quantum simulators are based on the laws of quantum physics that allows to overcome the shortcomings of supercomputers and to simulate materials or chemical compounds, as well as to solve equations in other areas such as high-energy physics (European Commission, 2016; Acín, et al., 2018). They are highly controllable quantum devices that allow one to obtain insights into properties of complex quantum systems or solve specific computational problems inaccessible to classical computers (European Quantum Flagship and European Commission, 2020). Their main advantage over all-purpose quantum computers, however, is that quantum simulators do not require complete control of each individual component, and are thus simpler to build. Today's quantum simulators are already well developed and are expected to provide unprecedented insights into complex quantum systems and materials with potentially important applications for end-users in quantum chemistry, nuclear physics, material sciences, fluid mechanics, traffic-flow optimisation, routing, and cloud services (Acín, et al., 2018; European Quantum Flagship and European Commission, 2020).

(4) Quantum Sensing, Metrology and Navigation

The employment of quantum phenomena to achieve highly precise and accurate detection and measurement can be leveraged for a range of applications in sensing, metrology, and navigation (Kania & Costello, 2018, p. 5). Just as sensors are of crucial importance for military and security applications, quantum sensors are proving a step change in 'sensitivity or accuracy, sometimes of many orders of magnitude, or even alternative modalities not accessible to classical devices' (Pritchard & Till, 2014, p. 28). Particularly, several variants of quantum sensors and radars might enable in the future for militaries to detect stealthy, hidden, or underground targets; in addition to implement techniques for 'ghost' imaging, which typically involve non-quantum or 'classical' properties at present but could leverage quantum properties further in the future, and may have key applications in space-based intelligence, surveillance, and reconnaissance systems (Pritchard & Till, 2014; Acín, et al., 2018). In addition, the implementation of quantum clocks could be produced for timing with an enhanced greater precision and synchronisation, which could become a critical variable in modern military operations in navigation, imaging, object detection, and electronic warfare communications. In particular, for navigation a quantum 'compass' could also be created as a more accurate substitute for GPS, especially in denied environments. Overall, with these novel applications, governments and enterprises alike may underpin in the future geo-prospecting, chemical and materials analysis and characterisation, and most importantly, science from the sub-nano to the galactic scale, besides determining the fundamental constants relied upon for industry, commerce, security and defence (Acín, et al., 2018).

The advent of Quantum 2.0 introduces a new age of uncertainty, more like an apparent inescapable dilemma, in which governments, societies, and industries alike are left to wonder when and how the potential impact of QTs might occur. Though now nascent, quantum science and technologies have shown that advancements in the field are of great significance for this century due to their potential revolutionary ramifications, which are clearly exacerbating international competition amongst global powers (Kania & Costello, 2018; International Institute for Strategic Studies, 2019). Much like with nuclear weapons, scientists and policymakers involved in developing QTs are unable to predict the total utility of these technologies or the power they can unleash. A quantum computer may not be capable of the physical destruction cause by a nuclear bomb, nevertheless, its unique potential implication can be considered the digital equivalent (Caughill, 2017).

The scientific community and the various governments across the globe are certain that advancements in this technology will disrupt current technology used in almost every sector and industry, generating perhaps the greatest social-political impact of our time. Nevertheless, its impact on global politics, and more specifically, on the dynamics of the international system will be defined by how nation-states adopt and utilise these technologies, rather than on the raw characteristics of the technology *per se* (Horowitz, 2010). These implications of QTs thus cannot be taken for granted. This dissertation will concentrate on analysing the current decision-making of major global powers towards the adoption of QTs and their potential applications in order to truly assess how the future trajectories in this technology might end up influencing global power politics and the international system dynamics in the near future. While Horowitz's AC theory cannot purport to provide exact answers for the full potential of QTs, it may prove useful to predict future patterns and to know the right questions to ask (Horowitz, 2010, p. 5). For instance, if these technologies do have such dangerous potential, why are major global powers pursuing them? What are the motivations and constraints behind major global power's decision to succeed in the development of such technologies? And most importantly, how these can influence the balance of power and the structure of international competition and warfare in the near future.

In particular, AC theory may not only allow for the development of a deeper understanding of current decision-making and behaviour of major global powers towards the adoption of QTs, but may also provide a meaningful explanation for the spread of these technological innovations and the reasons why countries are interested in developing such technologies. As different innovations have spread throughout the international system differently, and the way they spread have had a large effect on key issues in international politics, such as the balance of power and the probability and intensity of future warfare, studying the diffusion of such technologies may reveal the real significance of QTs.

The following section elaborates on the specific research methodology and methods used to conduct this study and discusses how the analysis of empirical evidence—based on documentary and discursive data of China, the United States, and the European Union—can be used to provide a better understanding of how major global powers make choices about the adoption of QTs and what the potential implications of these technologies can be in the near future.

CHAPTER 3: RESEARCH METHODOLOGY AND METHODS

This chapter outlines the research methodology and methods applied for conducting this study. The first section examines the ontological and epistemological assumptions that underlie research methodologies and elaborates on why this dissertation adopted a mixed methods approach. The second section addresses the role of theory and the two specific research methods implemented for conducting this study—document analysis and discourse analysis. The third section describes the research process of this study, including the process of collecting, displaying, and interpreting the data gathered.

3.1 Research Methodology

In social science, research methodology refers to the general approach of investigation to research topics (Silverman, 2000). The adoption of any specific approach to conducting research is grounded on the researcher's underlying assumptions on the nature of reality (ontology) and acceptable knowledge of that reality (epistemology). These assumptions guide the choices researchers make concerning the methods of data gathering and forms of data analysis, as well as the use of specific theories (Silverman, 2000).

Although there are other distinctions in research modes, the most common approaches to research are formed by quantitative and qualitative approaches. Bryman (2012) defines quantitative research as a research strategy 'that emphasizes quantification in the collection and analysis of data' that typically entails a deductive approach to the relationship between theory and research, in which the accent is to be placed on the testing of theories (pp. 35-36). The ontological assumption of the quantitative paradigm is that 'empirical reality is objective and external to the subject' (Ryan, et al., 2002, p.

41).Within the quantitative research methodology hence knowledge is assumed to be gathered mostly through positivistic research that can help predict and most importantly *explain* 'what does or will happen' (Ryan, et al., 2002, p. 75). It is important to note, however, there may be other approaches to quantitative research than positivism.

By contrast, qualitative research is based on the ontological assumption that reality is 'emergent, subjectively created, and objectified through human interaction' (Creswell, 2003, p. 53). This approach to research can be construed as a research strategy 'that usually emphasizes words rather than quantification in the collection and analysis of data' and 'that predominantly emphasizes an inductive approach to the relationship between theory and research, in which the accent is to be placed on the generation of theories' (Bryman, 2012, p. 36). Yet it can also be used for testing or extending existing theories rather than just merely creating new ones. Knowledge in this type of research is expected to be gathered by 'studying things in their natural settings, and attempting to make sense of (or interpret) phenomena in terms of the meanings people bring to them' (Denzin & Lincoln, 1994, p. 2). Whilst quantitative research typically seeks to explain knowledge acquired through (mostly) positivist approaches, qualitative research often involves more of an interpretive approach to better *understand* the social world (Hollis & Smith, 1990).

The suitability for adopting one of these approaches, nevertheless, is determined by the context, purpose, and nature of the research study in question, as well as by the researcher's personal experiences, and the outcomes the researcher wants to reach (Bryman & Burgess, 1994; Creswell, 2009). According to Silverman (2004), qualitative research should be carried out to investigate and discover issues about the problem on hand, either because very little is known or because there is usually uncertainty about nature, dimensions, and features of the study in question. If the focus of the study is on the 'how' (and 'why') questions within processes emerging in a 'real life' context, the methodology of qualitative research appears to be the most suitable methodology to adopt (Silverman, 2004; Flick, 2006; Patton, 2002; Denzin & Lincoln, 1994; Given, 2008). However, since the research design of this dissertation is based on *explaining* the causes for which major global powers are adopting QTs and *understanding* the real meaning (reinforced by postures, behaviours, and expectations) countries have towards those technologies, the dissertation adopted a mixed methods approach—that is, 'the type of research that combines elements of quantitative and qualitative research approaches for the broad purposes of breadth and depth of understanding and corroboration' (Creswell, 2009, p. 4).

The mixed methods approach involves the collection, analysis, and integration of quantitative and qualitative data on the same research problem (Creswell, et al., 2003; Hesse-Biber, 2010). By adopting such an approach, it is possible to produce distinctive benefits, such as triangulation and comprehensiveness, and to draw even stronger inferences that cannot be generated by an individual approach (Johnson, et al., 2007; Robson & McCartan, 2015). Through its unique capacity and in-depth tools, mixed methods research assisted to better explain and understand the underlying values societies and dominant powers give to QT and why this matters for power politics and future warfare.

3.2 Methods for research and the role of theory

Within qualitative, quantitative, or mixed methods approaches, the methodology and methods implemented to conduct research are often linked to the adopted theoretical framework (Silverman, 2000). While the methodology of a research refers to 'the general approach of investigation to a research topic', and methods refers to 'the specific research techniques utilised', theory is used to depict those sets of concepts used to define and explain certain phenomenon (Silverman, 2000, p. 77). The theoretical framework applied in a study can thus play a strategic role in framing and conducting the form of research (e.g. by influencing the development of purpose statements, research questions, data collection and data analysis) (Given, 2008). Before discussing the research methods adopted in this study, this section will therefore briefly outline the theoretical framework implemented for this study.

The theoretical framework—as a lens to study QT and its influence in global power politics—is inspired by Michael Horowitz's Adoption-Capacity (AC) theory. As referenced throughout the dissertation, AC theory suggests that the impact of any technology, depends, in part to its potential basic uses (Horowitz, 2010). It posits that the impact of technological change on global politics depends much more on how governments and organisations make choices about the adoption and use of new technologies than on the raw characteristics of technologies *per se* (Horowitz, 2010). A 'nation-state's response to an innovation is the greatest consequence for international security and power politics' (Horowitz, 2010, p. 44). Considering that Horowitz expounds on the possible existence of a series of incentives and constraints that shape nation-states' eventual response strategy to an innovation—such as international competition and norms, cultural or national pride, domestic politics, as well as implicit assumptions of capabilities and threats—AC theory guides this study by pointing out which variables and conditions the dissertation needs to appraise in order to make its own assessment on the adoption of QTs and future potential implications. Taking these notions, the research question and objectives for this dissertation were accordingly defined as follows:

Research Question:

How advancements in quantum technology (QT) might influence power politics in the foreseeable future?

Research Objectives:

1. To determine which are the strategic ambitions of major global powers in QT and the extent to which these can impact on the structure of balance of power
2. To assess what is the discourse, postures, behaviours and overall expectations of major global powers towards QT adoption

As a philosophical underpinning for this mixed methods study, AC theory shapes the types of questions asked, informs how data is to be collected and analysed, and guides all aspects for conducting this study. Moreover, the adopted theoretical framework, research question and objectives, indicate what type of data needs to be collected and analysed for identifying and understanding the emerging ideals underpinning power projectability in the quantum field, such as: what type of QTs are countries mainly investing in and why; are there any specific fields or domains in which countries are most focused on developing such technologies; are there any organisational challenges countries are facing for adopting QTs; are they looking to cooperate amongst states for developing these technologies, or are they driven by global competition for power; is there any clear sentiment (positive or negative) in regard to the development of these technologies; are countries focusing on developing new quantum capabilities; and, is there a common perception of threats amongst states or are these actors feeling individually threatened by each other's capabilities.

The reason behind collecting and analysing these variables is due to the fact that they can help to better understand the background of each actor, the various dimensions, and the extent to which major global powers are adopting QTs (e.g. for military and/or commercial applications), why, and how it might affect the balance of power and structure of international competition. By including a sentiment variable for analysis, this dissertation can also make further inferences on countries' current decision-making and behaviour towards the adoption of QTs.

On the one side, the features studied under this framework reflected the need in identifying and assessing the causes that influence major global power's decision for QT's implementation. This was captured by conducting extensive documentary analysis primarily focused on policies and initiatives developed by China, the United States (US), and the European Union (EU) that suggest an explanation for their QT adoption (Section 3.3.1). Document analysis is a social research method that refers to the systematic procedure for reviewing or evaluating documents—both printed and electronic material—relevant for the study in question (Bowen, 2009). Similar to other analytical methods in qualitative research, document analysis requires that data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Merriam, 1988; Corbin & Strauss, 2008).

On the other side, this dissertation utilised discourse analysis—focused on the verbal act—to uncover a different dimension of the same phenomena, e.g. how these actors' identities, cultural background, and sentiment towards this technology shape their postures, behaviours, and their overall expectations of harnessing QT. According to Potter (1997), discourse analysis accentuates the way versions of the world, society, events, and inner psychological worlds are produced in discourse. As discourse analysis is hermeneutic and phenomenological in nature, it involves 'an analytical process of deconstructing and assessing critically language use in a social context' (Miles, 2012, p. 369) Thus, discourse analysis enables a deeper understanding and interpretation of socially produced meanings that go beyond the technical pieces of language, namely words and sentences (Jorgensen & Phillips, 2002; Labuschagne, 2003; Bowen, 2009) .

The use of both documentary and discursive data, although part of the same discourse, allowed for written and spoken communication to be analysed through a combination of 'traditional' (quantitative) content analysis, based on word and phrase count, and a (qualitative) discourse analysis that focused on the language used and the contextual factors in which the documents and speeches emerged (i.e. sentiment analysis). The analytical procedure mainly entailed finding, selecting, appraising, and coding data contained in various documents and spoken forms of communication. This was performed by utilising excerpts, quotations, entire passages, and parts of speeches that were then organised into themes for uncovering meaning and discovering patterns of the research problem. This will be explained in more detail in the following sub-section.

3.3 The research process of this study

This section outlines the research strategy to define, collect, and analyse data. In addition, this section draws upon how both qualitative and quantitative data were combined to present more comprehensive and detailed results to the research question and objectives.

3.3.1 Data Collection

The first step in order to address the aforementioned research objectives involved collecting data from a variety of sources. As such, this dissertation sought insight from two primary data groups. Firstly, this dissertation examined those key quantum-related strategies of China, US and EU over the past five years, which include:

- *China's 13th Five-Year Plan on* (2016-2020)
- *Made in China* (2015-2025)
- *U.S. National Quantum Initiative Act* (2018)
- *U.S National Strategic Overview for Quantum Information Science* (2018)
- *EU Quantum Manifesto* (2016)
- *EU Quantum Flagship* (2018-2028)

Secondly, this dissertation analysed recent speeches and press releases by those same major global powers and their top government officials (e.g. from President Donald Trump and U.S. Chief Technology Officer Michael Kratsios; President Xi Jinping and Premier Li Keqiang; President of the European Commission Ursula von der Leyen and former European Commissioner for Digital Single Market and Vice President of the European Commission, Andrus Ansip). Equally important to note is that secondary data was utilised to complement primary source information. For instance, some information from other academic studies and publications—including reports, commentaries, and journal articles that study the relationship between great powers and the adoption and implementation of QTs—were examined and used to reinforce part of the assessment in Section 4; these also included those relevant investigations of country-specific programmes and projects on the quantum field. As QT encompasses a variety of security actors from public and private actors, to organisations and individuals, which all have significant data published online, this dissertation was very critical when examining the documented evidence provided by the research methods used in secondary data groups. By taking extra time to trace all sources of these documents and search for supporting evidence, this dissertation validated data appropriately.

3.3.2 Data Analysis

Bogdan and Biklen (2007) define data analysis as 'working with data, organising it, breaking it into manageable units, coding it, synthesising it, and searching for patterns' (p. 145). For this dissertation, the analysis of documentary and discursive data is presented by three specific sub-processes—data reduction, data display and data interpretation. A computer assisted qualitative data analysis software (CAQDAS) package, i.e. MAXQDA, was utilised to assist in analysing documentary and discursive data. MAXQDA is a world-leading software programme for qualitative and mixed methods research that allows managing, coding, and displaying research data (MAXQDA, n.d.). MAXQDA offers a variety of tools that assist in exploring data in a systematic way, as it will be discussed throughout the following sub-sections. The implementation of this software allows far more efficient and effective work processes by saving time and gaining deeper insight into the data used.

3.3.2.1 Data reduction: detailed reading and coding

The first step for the analysis of data is data reduction (O'Dwyer, 2004; Huberman & Miles, 1994). Data reduction is the translation of information from one form to another form to simplify problems of analysis, storage, and dissemination to others (Selltiz, et al., 1981). The primary objective of data reduction is to reduce the data without significant loss of information. For this dissertation, data reduction was carried out by performing a careful and detailed re-reading and appraisal of documents to select specific data and perform coding and category construction. Codes can be simple labels or names for complex structures (Kuckartz & Rädiker, 2019, p. 8), for which a kind of thematic analysis is implemented in this study, as a form of pattern recognition within the data, with emerging themes becoming the categories (or codes) for analysis.

Since documents were collected to analyse how advancements in QT influence global power politics by focusing on the discourse, (explicit or implicit) strategic ambitions, postures, behaviours and expectations major global powers may have towards QT advancements, the coding process mainly involved identifying and coding the emerging ideals underpinning power projectability, namely defined in Section 3.2. It involved a deductive category formation where the entirety of these ‘ideals’ were integrated into a *hierarchical code* system that consists of top-level codes and multiple levels of sub-codes (See Figure 1). In this code system, the eight main categories (top-level codes) are defined as: “Budget”, “QT type”, “Domain”, “Sector”, “Cooperation”, “Competition”, “Sentiment”, “Q Capabilities” and “Threats”; some of which have their own specific sub-codes (or sub-categories)

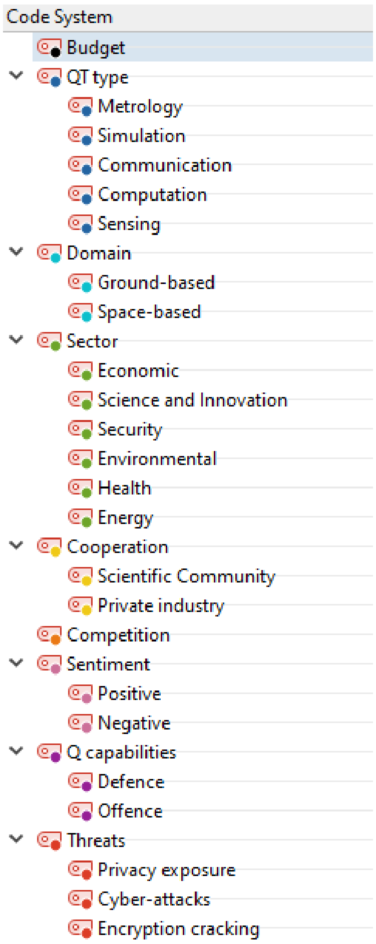
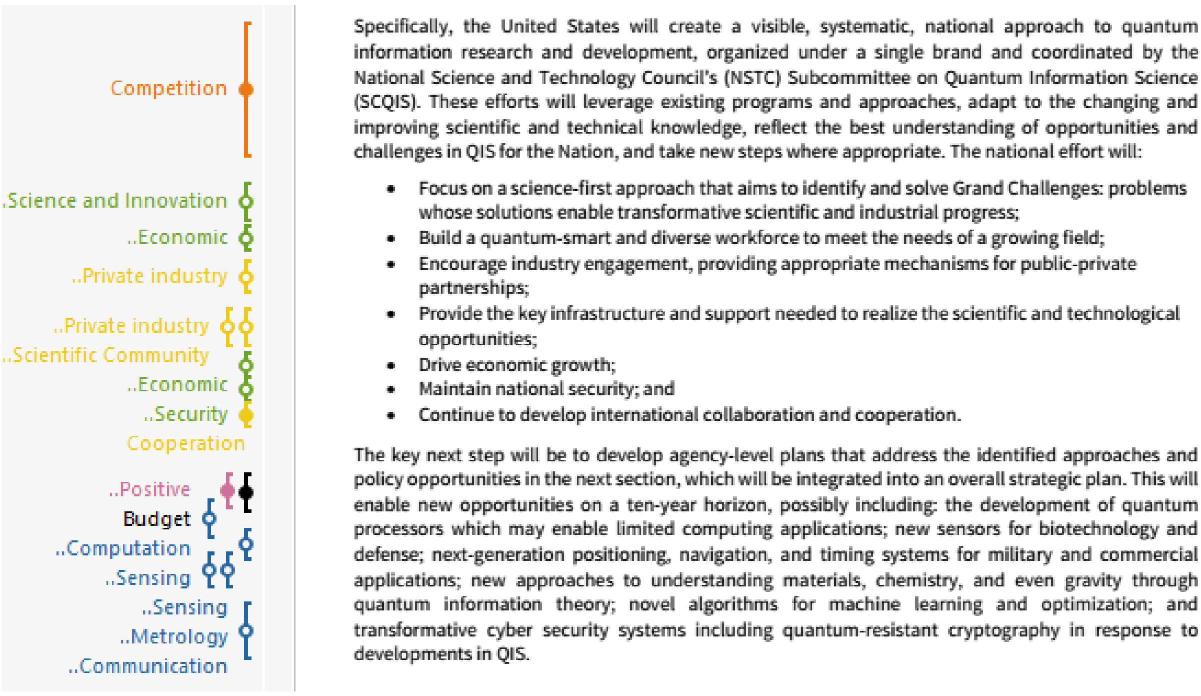


Figure 1. MAXQDA Code System Structure

Given that this dissertation considers data from three different actors that may have different standpoints on power projectability and QT implication, such hierarchical code system provide a much clearer overview of the findings of these actors (e.g. by highlighting similarities and differences) in QT adoption, in addition to revealing the factual meaning contained in the different sources of data. The comparison of each top-level code and the respective sub-categories are displayed and analysed in the following sections, with a detailed explanation for the Code Matrix Browser (CMB) tool.

All sections of documentary and discursive data addressing one of these key top-level codes and the respective sub-categories were marked by using the coding function in MAXQDA, which allows a quick and easy identification and access to themes throughout the analysis (See Figure 2). All documentary and discursive data were analysed repeatedly to ensure consistent coding.



Specifically, the United States will create a visible, systematic, national approach to quantum information research and development, organized under a single brand and coordinated by the National Science and Technology Council's (NSTC) Subcommittee on Quantum Information Science (SCQIS). These efforts will leverage existing programs and approaches, adapt to the changing and improving scientific and technical knowledge, reflect the best understanding of opportunities and challenges in QIS for the Nation, and take new steps where appropriate. The national effort will:

- Focus on a science-first approach that aims to identify and solve Grand Challenges: problems whose solutions enable transformative scientific and industrial progress;
- Build a quantum-smart and diverse workforce to meet the needs of a growing field;
- Encourage industry engagement, providing appropriate mechanisms for public-private partnerships;
- Provide the key infrastructure and support needed to realize the scientific and technological opportunities;
- Drive economic growth;
- Maintain national security; and
- Continue to develop international collaboration and cooperation.

The key next step will be to develop agency-level plans that address the identified approaches and policy opportunities in the next section, which will be integrated into an overall strategic plan. This will enable new opportunities on a ten-year horizon, possibly including: the development of quantum processors which may enable limited computing applications; new sensors for biotechnology and defense; next-generation positioning, navigation, and timing systems for military and commercial applications; new approaches to understanding materials, chemistry, and even gravity through quantum information theory; novel algorithms for machine learning and optimization; and transformative cyber security systems including quantum-resistant cryptography in response to developments in QIS.

Figure 2. The Coding Process in MAXQDA
(Source data: US National Strategic Overview for Quantum Information Science)

3.3.2.2 Data display and interpretation: analysing key themes and interpreting findings

The second sub-process for the analysis of data is data display (O'Dwyer, 2004; Huberman & Miles, 1994). Data display is the process to visually display the reduced data through the creation of detailed matrices of key themes and emerging patterns. There are many ways for displaying data, including charts, diagrams, and figures that enable data to be organised and summarised appropriately. In conducting the analysis of documentary and discursive data on QT and its influence in global power politics, this dissertation mainly used MAXQDA for the display of data, which allows one to generate various overviews for analysis of top-level codes, sub-categories, and their frequencies automatically. For this stage, MAXQDA proved to be very flexible in representing data by allowing to use document groups and document sets to create different organisational structures for the data material.

On one side, and as illustrated in Figure 3, a CMB was used to provide an overview of how many coded segments were assigned to each document group. The CMB is constructed as follows: document groups (i.e. sets of documentary and discursive data from China, US, and the EU) are listed in the columns while codes are listed in the rows. The symbol at the conjunction points represents the number of coded segments that were coded with a particular code (plus their weight filter). The larger the symbol, the more coded segments were assigned to the code in question. Figure 4 and Figure 5 are also used as CMBs to better display the percentiles of coded segments per document groups and per specific categories. The specific documentary and discursive data considered under each document group is displayed in Figure 6, along with the total number of codes produced for each source of data.

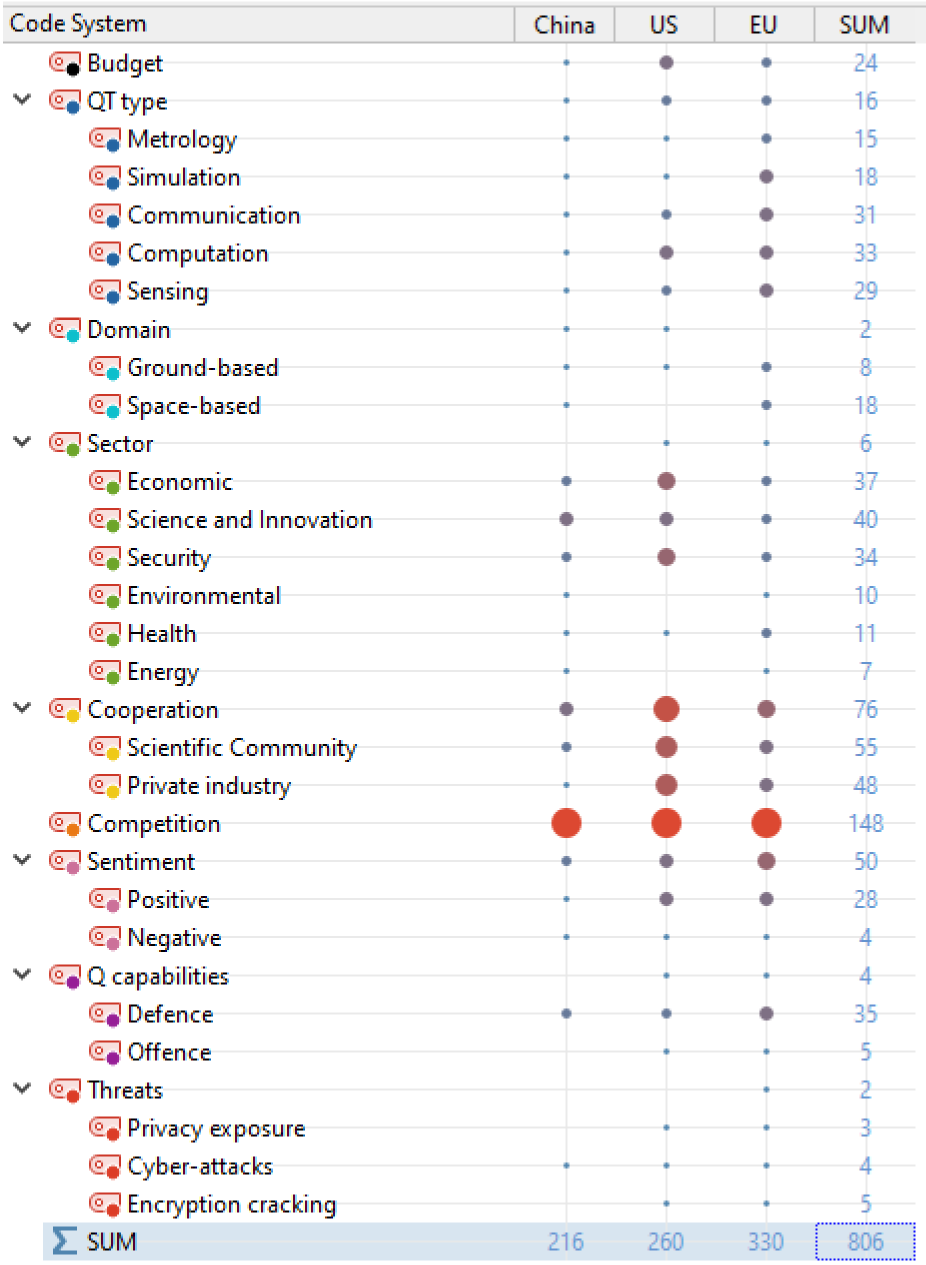


Figure 3. Coded Segments in MAXQDA'S Code Matrix Browser (CMB)

	China	US	EU
Budget	0.9%	5.8%	2.1%
QT type	2.3%	1.9%	1.8%
Metrology	1.4%	1.2%	2.7%
Simulation	1.4%	0.4%	4.2%
Communication	2.8%	2.7%	5.5%
Computation	2.3%	4.2%	5.2%
Sensing	1.9%	2.7%	5.5%
Domain	0.5%	0.4%	
Ground-based	0.5%	0.4%	1.8%
Space-based	2.3%		3.9%
Sector		1.2%	0.9%
Science and Innovation	7.9%	5.8%	2.4%
Economic	5.6%	6.5%	2.4%
Security	4.6%	6.5%	2.1%
Environmental	2.3%		1.5%
Health	1.4%	0.4%	2.1%
Energy	1.4%		1.2%
Cooperation	10.6%	11.5%	7.0%
Scientific Community	5.6%	9.2%	5.8%
Private industry	2.8%	8.5%	6.1%
Competition	29.2%	13.5%	15.2%
Sentiment	5.6%	5.4%	7.3%
Positive	0.5%	4.6%	4.5%
Negative	0.5%	0.4%	0.6%
Q capabilities		1.2%	0.3%
Defence	5.6%	2.3%	5.2%
Offence		0.8%	0.9%
Threats			0.6%
Privacy exposure		0.8%	0.3%
Cyber-attacks	0.5%	0.8%	0.3%
Encryption cracking		1.2%	0.6%
SUM	100.0%	100.0%	100.0%
N = Documents	5 (29.4%)	7 (41.2%)	5 (29.4%)

Figure 4. Percentile of Coded Segments per Document Group

	China	US	EU	Total
Budget	8.3%	62.5%	29.2%	100.0%
QT type	31.3%	31.3%	37.5%	100.0%
Metrology	20.0%	20.0%	60.0%	100.0%
Simulation	16.7%	5.6%	77.8%	100.0%
Communication	19.4%	22.6%	58.1%	100.0%
Computation	15.2%	33.3%	51.5%	100.0%
Sensing	13.8%	24.1%	62.1%	100.0%
Domain	50.0%	50.0%		100.0%
Ground-based	12.5%	12.5%	75.0%	100.0%
Space-based	27.8%		72.2%	100.0%
Sector		50.0%	50.0%	100.0%
Science and Innovation	42.5%	37.5%	20.0%	100.0%
Economic	32.4%	45.9%	21.6%	100.0%
Security	29.4%	50.0%	20.6%	100.0%
Environmental	50.0%		50.0%	100.0%
Health	27.3%	9.1%	63.6%	100.0%
Energy	42.9%		57.1%	100.0%
Cooperation	30.3%	39.5%	30.3%	100.0%
Scientific Community	21.8%	43.6%	34.5%	100.0%
Private industry	12.5%	45.8%	41.7%	100.0%
Competition	42.6%	23.6%	33.8%	100.0%
Sentiment	24.0%	28.0%	48.0%	100.0%
Positive	3.6%	42.9%	53.6%	100.0%
Negative	25.0%	25.0%	50.0%	100.0%
Q capabilities		75.0%	25.0%	100.0%
Defence	34.3%	17.1%	48.6%	100.0%
Offence		40.0%	60.0%	100.0%
Threats			100.0%	100.0%
Privacy exposure		66.7%	33.3%	100.0%
Cyber-attacks	25.0%	50.0%	25.0%	100.0%
Encryption cracking		60.0%	40.0%	100.0%
Σ SUM	26.8%	32.3%	40.9%	100.0%
# N = Documents	5 (29.4%)	7 (41.2%)	5 (29.4%)	17 (100.0%)

Figure 5. Percentile of Coded Segments per Top-level codes and Sub-codes

Documents	806
China	216
Press Release: State Council on Comprehensively Strengtheni...	38
Speech: Minister of Science and Technology Wang Zhigang	16
Speech: Li Keqiang at the National Science and Technology	17
Made in China	47
Thirteenth Five-Year Plan	98
USA	260
Press Release: President Trump's FY 2021 Budget Commits	15
Press Release: America Achieved Quantum Supremacy	6
Press Release: America Will Dominate Industries of the Future	20
Speech: Americas Global Tech Leadership	30
Speech: GES 2019 Launch Deputy Assistant to the President	5
National Quantum Initiative Act	36
National-Strategic-Overview-for-Quantum-Information-Science	148
EU	330
Speech: Vice-President Andrus Ansip	20
Speech: President-elect von der Leyen	39
Press Release: Quantum Technologies Flagship	40
Quantum Flagship	129
Quantum Manifesto	102

Figure 6. Document Matrix

On the other side, for producing a comparative analysis on the (qualitative) content of the coded segments, a MAXQDA Interactive Quote Matrix (IQM) was utilised (See Figure 7 below). The function allows to easily compare coded data (qualitative data) and code frequencies (qualitative data transformed into quantitative data) through an interactive segment matrix (MAXQDA, n.d.). Within the matrix, the group of actors being analysed for this study forms the columns, the codes are listed in the rows, and the cells comprise the individual coded segments to effectively compare the content of each group.

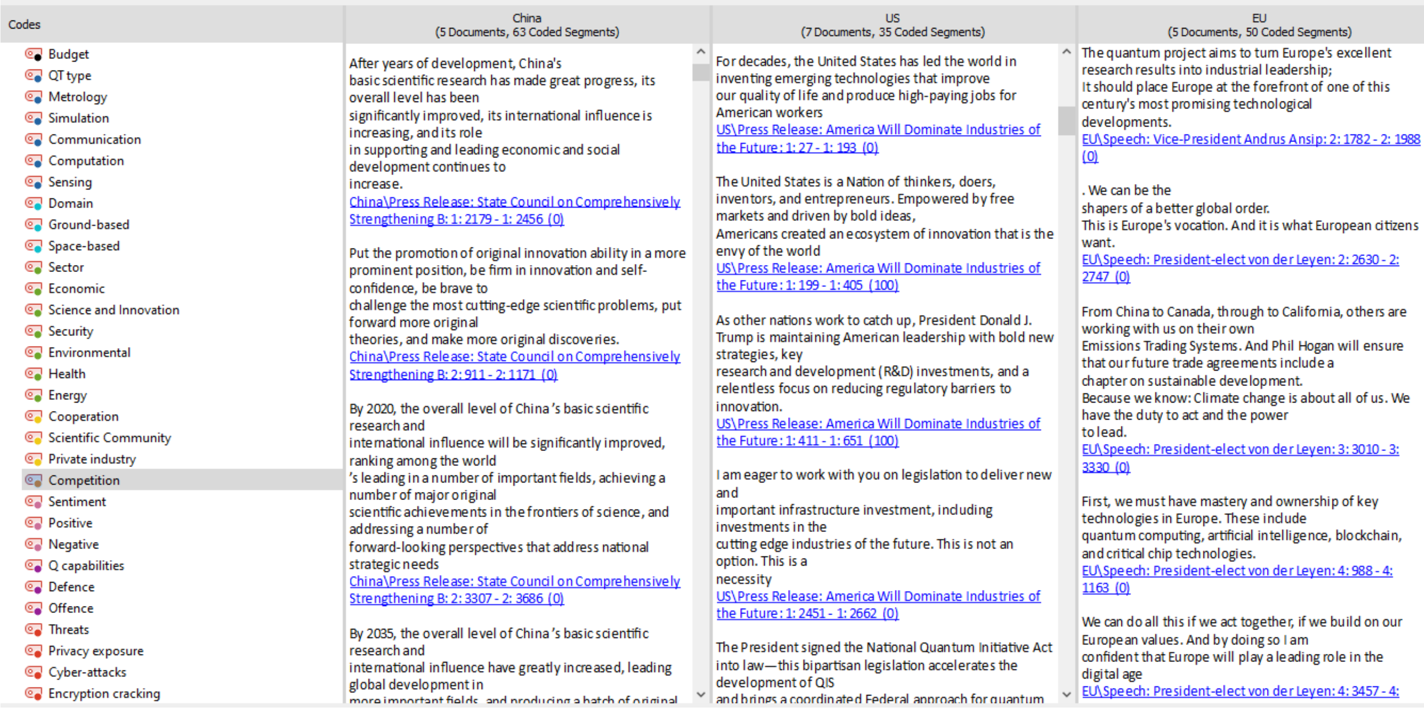


Figure 7. Interactive Quote Matrix (IQM): Results table for the comparison of coded segments for code "Competition"

As a visual tool, both the CMBs and IQM contribute significantly to the understanding of the paths taken by these major global powers in the quantum field. Through a combination of quantitative content analysis (CMB) that concentrates on word and phrase count, and a qualitative discursive analysis (IQM), that focuses on the language used and contextual factors, data was easily interpreted, analysed, and critically assessed.

The final step in the analysis was the interpretation of data (O'Dwyer, 2004), which involved efforts to interpret the reduced data sets, i.e. the overviews and matrices generated in the previous steps. In this step, all figures were examined in detail, and emerging key themes were further created and critically assessed. The analysis of documentary and discursive evidence, along with the implementation of the chosen theoretical framework, continues throughout the entire research process in order to relate the findings to prior literature and theory, and to find contradictions or limitations within the gathered data.

CHAPTER 4: FINDINGS AND ANALYSIS OF COUNTRY-SPECIFIC PROGRAMMES, INITIATIVES, AND STRATEGIES

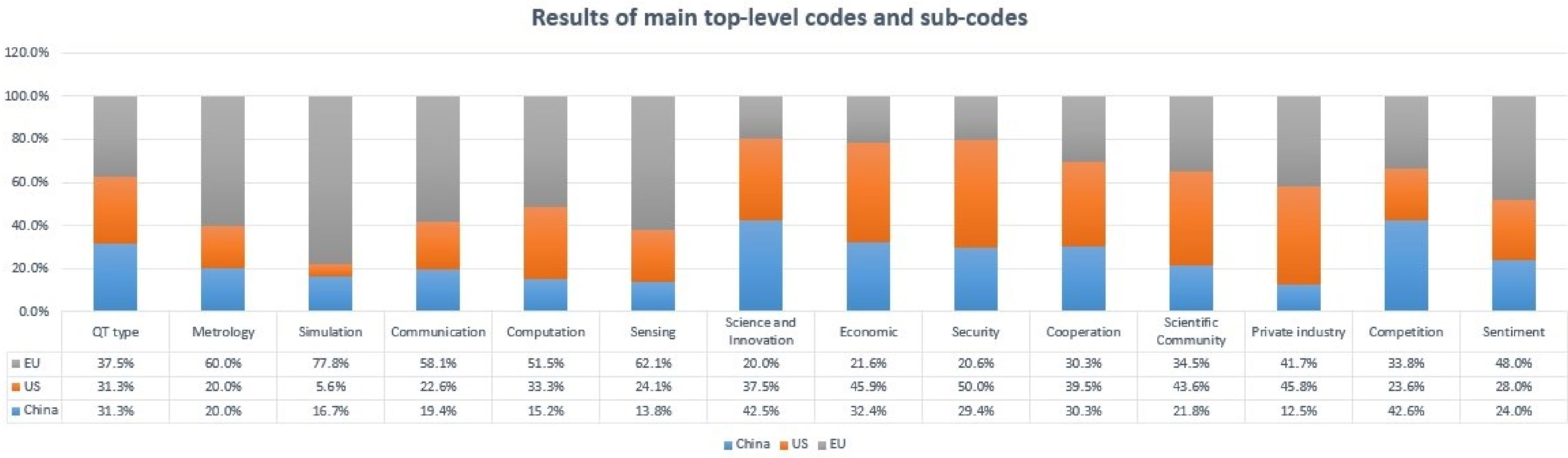
In this chapter the analysis of documentary and discursive evidence is discussed. In addition, the different dimensions relevant for understanding current decision-making, postures, behaviours, ambitions, and expectations of major global powers regarding the adoption and implementation of QTs are assessed. As previously mentioned in the background of the literature and in the methodological chapter, AC theory is used as a lens to discuss these dimensions with the aim to provide valuable insight into the incentives and constraints that are currently shaping the response strategy of major global powers to adopt QTs. Accordingly, this chapter presents its own assessment on the adoption of QTs and potential implications for the balance of power, the structure of international competition, and future warfare.

Deriving from the results of the hierarchical code system, and the MAXQDA CMBs and IQM, data evidence indicates that the current decision-making and behaviour of China, the US, and the EU towards the adoption of QTs are primarily concentrated on five of the eight top-level categories previously defined in Section 3.3.2.1, i.e. “QT type”, “Sector”, “Cooperation”, “Competition”, and “Sentiment” (See Figure 8 below).

	China	US	EU
Budget	0.9%	5.8%	2.1%
QT type	12.0%	13.1%	24.8%
Domain	3.2%	0.8%	5.8%
Sector	23.1%	20.4%	12.7%
Cooperation	19.0%	29.2%	18.8%
Competition	29.2%	13.5%	15.2%
Sentiment	6.5%	10.4%	12.4%
Q capabilities	5.6%	4.2%	6.4%
Threats	0.5%	2.7%	1.8%
Σ SUM	100.0%	100.0%	100.0%
# N = Documents	5 (29.4%)	7 (41.2%)	5 (29.4%)

Figure 8. Results from MAXQDA highlighting highest percentages per categories

From these five categories some of their own specific sub-codes make distinctive inferences about the adoption and intended trajectory in advanced quantum science and technologies (e.g. the sub-codes 'Economic', 'Science and Innovation', 'Security', 'Scientific Community', 'Private Sector', as well as the specific forms of technologies in the quantum field that these actors are mostly interested in developing). Figure 9 is used to better explain these categories and sub-codes in terms of their individual percentages produced by the data findings. From these categories and sub-codes, this dissertation in the following country-specific sections thus discusses the main emerging themes (or most influential determining factors) that shape major global powers' trajectory on the quantum field and assesses potential future implications.



	QT type	Metrology	Simulation	Communication	Computation	Sensing	Science and Innovation	Economic	Security	Cooperation	Scientific Community	Private industry	Competition	Sentiment
EU	37.5%	60.0%	77.8%	58.1%	51.5%	62.1%	20.0%	21.6%	20.6%	30.3%	34.5%	41.7%	33.8%	48.0%
US	31.3%	20.0%	5.6%	22.6%	33.3%	24.1%	37.5%	45.9%	50.0%	39.5%	43.6%	45.8%	23.6%	28.0%
China	31.3%	20.0%	16.7%	19.4%	15.2%	13.8%	42.5%	32.4%	29.4%	30.3%	21.8%	12.5%	42.6%	24.0%

Figure 9. Results of main top-level codes and sub-codes

4.1 China

The key determinants of the Chinese government's adoption and intended exploitation of QTs stem from its ambition to *become* a world-class technology superpower (科技强国), highlighted not only by the science and innovation sector in the CBMs, but also through the coded segments referring to economic and international competition, as well as being further revealed by the sentiment analysis. The Chinese government, in the last decade, has pushed forward industrial reforms and laid out ambitious plans to drive domestic science and technological innovation to develop and produce high-end products and new technologies, including those of QT (Nouwens & Legarda, 2018). Figure 3 and Figure 9 demonstrate that, between the data from all actors, China has shown a greater interest in QTs to advance in science and innovation. For instance, with its 13th Five-Year Plan (FYP)—i.e. the country's key special planning in the scientific and technological innovation field—and industry-specific FYPs over the 2016-2020 period, along with its "Made in China 2025"(MIC) initiative, China has significantly stepped up with the prioritisation of advancing innovation, achieving technological self-sufficiency, and enhancing independent innovation capabilities to become a technology superpower with an industry and technology system that is 'globally competitive, indigenous, and controllable' (State Council, 2015; State Council, 2016).

Under the leadership of President Xi Jinping, China has also recognised and prioritised the strategic development of QIS and QTs to enhance economic and military dimensions of national power, besides its capabilities for future national competitiveness. Particularly, these variables are drawn from Figure 3 and Figure 4, in which, out of the 216 coded segments of China's documentary and discursive data, the notion of competitiveness composes a 29.2 percent of China's entire data. Additionally, when comparing the data gathered from all actors, China alone recorded the highest percentage of 42.6 percent, which reflects its impetus on great power competition. Correspondingly, based on China's 13th FYP, MIC 2025, and speeches of top-level government officials, this dissertation examines various themes that shape China's current decision-making, postures, behaviours, ambitions, and expectations into the development of QIS and QT adoption:

(1) Competitive Advantage and National Pride

In the documentary and discursive data, China reveals that it aspires to lead Quantum 2.0. However, it can be inferred that this motivation is not only driven by the ambition to achieve a strategic competitive advantage but can also be partially motivated by national pride. This is highlighted through the variables of international competition and the sentiment analysis from the MAXQDA IQM, as well as by the American technology experts, Elsa Kania and John Costello (2018, p. 7), who argue that China not only seeks to leverage QTs to leapfrog its main strategic competitor, the US, but that there are likely also considerations of national prestige against the backdrop of President Xi's call for rejuvenation and national narrative of the 'Chinese Dream'(中国梦), which have motivated efforts to maximise the attention for milestones in QIS and QTs.

At the one hand, data evidence suggests that strategic competitive advantage motivates China to adopt and develop QTs, as China seeks to close the gap with Western countries in the field of science and technological innovation (State Council, 2016). The literature shows that throughout the information technology revolution, the US has been the epicentre of new technologies, reaping the full commercial and military benefits (Kania & Costello, 2018; Verhagen, et al., 2019). However, the current situation with

QTs demonstrates that US pre-eminence in this information technology will not necessarily confer substantial advantage in the pursuit of QIS and QTs. Rather, China is now competing on par with the US, or potentially even achieving a first-mover advantage and attain future market and military dominance in these new technologies. As China aims to become the global leader in innovation by 2035 (State Council, 2016), developments in QT thus feature prominently in its science and technological innovation discourse, strategies, programmes and projects, with increasing government-led investments in the last few years particularly in quantum computing, quantum communications, as well as quantum simulation, sensing, metrology, and navigation. While the total level of funding allocated to develop these technologies is not fully disclosed in China's strategies (See 'Budget' in Figure 8), some studies suggest that it is expected to exceed billions of RMB in the years to come, becoming a budget that is 10 times higher than that of its closest competitors (i.e. the US and the EU) (Kania & Costello, 2018; López, 2019; Verhagen, et al., 2019). Furthermore, the consistency and scope of funding allocated towards QIS, together with the protectionist measures applied on keeping QTs in China, can propelled it as the global leader on QTs (especially on space-based technologies) (Verhagen, et al., 2019).

On the other hand, the sentiment analysis for this study suggests that there are also considerations of national prestige to maximise publicity and attention for China's quantum capabilities and developments, such as the launch of the world's first quantum satellite, Micius (墨子), and the world's most extensive quantum communications system, "Quantum Beijing-Shanghai Trunk" (量子京沪干线). The official media, under the supervision of the Chinese government, seems to sometimes exaggerate advances in QT, whether to bolster Chinese leaders' narrative of China as a nation of innovation or to signal prowess to—or perhaps provoke undue concerns from—potential adversaries (Kania & Costello, 2018, p. 22). This to the extent to which it becomes difficult to evaluate the real progress of China's QT advances, as they may remain either highly classified or overstated. For instance, President Xi Jinping in his 2018 New Year's address, highlighted successes in research and development of quantum computers as a major achievement for China, claiming to be the country '*closest*' in achieving quantum supremacy (Xinhua, 2019)—which was not necessarily factually accurate.

Additionally, with a number of national-level plans (e.g. National Key Research and Development Plan 2016, 13th Five-Year National S&T Innovation Plan and the 13th Five-Year National Strategic Emerging Industries Development Plan), China's ambition and national pride to accelerate the construction of a '*socialist modernised powerhouse',* and further expand its influence around the globe through the promotion of Chinese 'attributes' in QIS and QTs, reflects the nation's true intended trajectory towards emerging as a true scientific superpower, especially against the West. As China's Premier Li Keqiang said at the National Science and Technology Award Conference (2020): *"…China will take Xi Jinping's socialist ideology with Chinese characteristics in the new era as the guide to implement a new concept of innovation, coordination, and openness to seize the world's new round of scientific and technological revolution…".*

(2) Commercialisation and Market Advantage

China, within its MIC 2025 initiative, has made the commercialisation of QTs a priority, as in the near future, the commercial potential of QTs could enhance China's economic dynamism, enabling it to seize market leadership in new industries (State Council, 2015). This is evidenced through Figure 9, such that between the data from all actors, China's QT adoption to stimulate the economic sector mainly through commercialisation composes the second highest percentage of 32.4 percent of the entire 'Economic' variable. The rapid growth of China's commercial potential in QTs is further evidenced based on metrics of patent applications filed in different disciplines, with China leading in quantum communication and second to the US in quantum sensors, while still only ranked fifth in quantum computing as of 2015 (The Economist, 2017). Most significantly, however, if China succeeds with the commercialisation of QTs, experts assess it would benefit from first-to-market advantage that, when combined with its manufacturing and human capital base, would enable it to achieve and sustain global leadership in quantum information solutions, as well as the next information revolution (Kania & Costello, 2018, p. 27).

The documentary and discursive evidence similarly indicates that China may be in prime position to be competitive in other fields or sectors, some of which could result in impressive research and commercial applications of QTs, including in complex biology and chemistry, as well as machine learning and artificial intelligence, as argued in the 13th FYP. China's quantum sensing and metrology applications could also be used in everything from medicine to oil and gas exploration, as well as for leveraging a new energy revolution, in which China could be in a favourable position to lead in the exploration of the thermoelectric particles of quantum materials (Kania & Costello, 2018; Costello, 2017).

These potential advantages, nevertheless, will much depend on the levels of alignment and cooperation between the Chinese government, scientific community, and private sector. According to Figure 8, the Chinese government's intention for cooperation to improve, enhance, and optimise China's QT advancements is recorded as the second highest with a percentage of 19 percent. Although, in reality this variable may be higher than recorded, provided that China does not fully disclose the type and purpose of these collaborations for the short and longer term. In the near future, if China continues in this trajectory it could ensure its success in the operationalisation and commercialisation of unhackable quantum communications, in its quest for dominance in quantum computing and quantum sensing.

(3) Quantum Talent

Deriving from those same dimensions of cooperation and international competition, the 13th FYP, MIC 2025, and discursive data, indicate that China's ambition to become a science and technology superpower (科技强国) is profoundly intertwined with its desire to develop a 'unique' ecosystem of first-class scientific talents and high-end industries, especially one that can succeed in developing major QIS and QTs breakthroughs in and for China (State Council, 2015). In addition to the large amount of investments that China is considering to develop QTs, its most critical resource for success in the field is talent. The government has thus doubled its efforts to implement a more open policy for attracting and collaborating with talented individuals in the scientific and technological field through the promotion and guarantee of national and international recruitment, such as the Thousand Talents Plan (千人计划), which has incentivised the recruitment of over 7,000 scientists in total as of January 2018, including among its number is Pan Jianwei, better known as the "Father of Chinese quantum science".

Beyond these talent plans, the Chinese government has also established a range of scientific and technological collaborations and partnerships with other countries to support exchange of scientific and technical personnel (State Council, 2016). These partnerships aim to promote China's 'excellence' through international collaborations in the field, gain global recognition in scientific advances, and restore and strengthen the integrity of China's scientific research and originality against common allegations of technology transfer and intellectual property theft. Although China is clearly capable of truly indigenous innovation in these technologies, such research partnerships and recruitment of world-class talents can be leveraged to advance in the quantum field and in other emerging technologies, as well to achieve impactful commercial, and perhaps future military, applications (Kania & Costello, 2018).

(4) Military Dimensions of National Power

The Chinese government considers QTs a priority for its military modernisation. Although there is no direct reference on the MIC 2025 or the 13^{th} FYP of China's QTs strategic implication on military dimensions, the discursive evidence reveals that QTs are emphasised as a strategic imperative for the military innovation of China. This has been widely stressed by President Xi Jinping and by the Chinese People's Liberation Army (PLA), which aims to pursuit emerging technologies that may have a potential to disrupt the current military balance (Boyd, 2019; Xinhua, 2017). China has thus included quantum communications and quantum computing as an integral part of a series of national science and technology (S&T) plans and programmes, namely the national strategy for military-civil fusion (or "civil-military integration," 军民融合), the 13^{th} Five-Year S&T Military-Civil Fusion Special Projects Plan (科技军民融 合发展专项规划), and the Shandong Province Quantum Technology Innovation and Development Plan (2018- 2025).

China's effort to 'promote the two-way transformation of military and civilian S&T achievements in quantum information technologies' (State Council, 2016), has great significance as QTs will be leveraged to support military purposes, including for the enhancement of defensive and possibly even offensive capabilities (Kania & Costello, 2018; Nouwens & Legarda, 2018). Against the backdrop of a broader campaign to enhance national cyber and information security, China would also be leveraging such immense capabilities that could convey a military strategic advantage over its adversaries. In particular, through the development of quantum communications and quantum networks, China intends to shift its most sensitive military, governmental, and commercial communications to more secure systems, distant to the threats of cyber espionage, foreign influence, cyber-attacks, privacy exposure or encryption cracking (Kania & Costello, 2018). Similarly, with the introduction of quantum navigation, radars, imaging and sensing, China expects to enhance its intelligence, surveillance, and reconnaissance (ISR) capabilities, including detection, domain awareness and targeting capabilities that could potentially undermine US intelligence capabilities and its advantage in stealth technologies (Kania & Costello, 2018; Verhagen, et al., 2019). As President Xi Jinping stressed during the 36th Politburo study session on cyber security (2016): *"…advancing indigenous innovation in quantum communications and other critical cyber and information technologies is a priority for the country…*" In the aggregate, these advances could support the continued emergence of the PLA as a true peer competitor in these new technological frontiers of military power, as argued by the Centre for a New American Security (2018, p. 2).

China's documentary and discursive evidence indicates at all levels that the prioritisation the country is giving to QTs and QIS is to fulfil its long-term ambition to become a world-class technology superpower. In its quest to achieve major technological breakthroughs, China's progresses in QT also indicate a critical juncture in the trajectory of the Chinese military innovation (modernisation) and great power techno-strategic competition (namely US-China power-rival competition).

The country's research agenda demonstrates that in the long-term China wants to rise as a powerhouse in QIS and QTs with well-defined strategic advantages. It wants to promote its 'excellence' in the scientific and technological innovation field, gain global recognition, in addition to restoring and strengthening China's scientific research integrity against common allegations made by Western countries of China's technology transfer and intellectual property theft.

At present, the data evidence shows that, if the ambitions of China succeed, QTs applications on computation, sensing, navigation, communications, among others, are set to radically shift the balance of power and transform future warfare, perhaps even possessing strategic significance on par with nuclear weapons, as argued by PLA strategists and officers (An Weiping [安卫平], 2016). In particular, through quantum communications and quantum computing, in which China is very well-positioned, China is expected to transform future warfare and impact on the strategic balance of power through the ability to reset the military, and deliberately the intelligence balance, in China's favour. For instance, if China succeeds in the shielding of key military and governmental communications, China could achieve a key advantage in peacetime and wartime competition, further exacerbating international competition and a security dilemma.

The documentary and discursive evidence also suggests that China has many other strong advantages in the quantum field which could place it at the forefront of this technological revolution. The country is not only the largest investor in the field, but also it is well-positioned to achieve first-mover advantages and attain future market and military dominance in this technology, as evidence suggests. Similarly, its rising economic dominance, multiple forms of tech transfer, talent recruitment programmes, and comprehensive state-level R&D funding programmes are allowing China to stay ahead of other major global powers (namely, the US) in this race. Moreover, its ambition and expertise in research, development, and application of these technologies could ensure that China is uniquely positioned to develop more advanced approaches in quantum science and technology in the near future.

4.2 United States (US)

US' adoption and development of QTs and QIS stems from its ambition to *maintain* the status quo, i.e. to preserve its global leadership and power, which is highlighted by the MAXQDA CMBs and IQM through the variables referring to economic and international competition, as well as by the sentiment analysis and the science and innovation variable. For decades, the US has led the world in producing emerging technologies that promise 'to fuel American prosperity far into the future, while improving the security of the country' (Office of Science and Technology Policy, 2019). In times of great power competition, President Donald Trump has thus taken different approaches to put America in a position to maintain its global leadership in different industries, including in QIS and QTs. This sense of competitiveness accounts for almost 14 percent of US' discursive and documentary data—namely in the US National Quantum Initiative Act 2018 (NQIA), National Strategic Overview for Quantum Information Science 2018 (NSOQIS), and speeches of top-level government officials.

Long-running US government investments in QIS and QTs, which are estimated at $1.275 billion over the next 10 years, have transformed this nascent field into a strategic pillar of the American research and development enterprise (Executive Office of the President of The United States, 2018; Verhagen, et al., 2019). Deriving from the dimensions of competition, economic, security, and science and innovation, the documentary and discursive evidence suggests that, through advances in QIS and QTs, the US not only seeks to preserve and extend its 'hegemony', but also to enhance economic and military dimensions of national power by improving its industrial (technological) base, generating new employment, and providing America with unparalelled national security benefits. Correspondigly, based on the US' NQIA 2018, NSOQIS 2018, and speeches of top-level government officials, this dissertation examines various themes that shape US' current decision-making, postures, behaviour, ambitions, and expectations into the development QIS and QT adoption:

(1) National Pride and Leadership

In its scientific and technological discourse, in which QT is deeply embedded, the US resonates with its long and very proud history of being a *free* country and having a *free* enterprise. Throughout the discursive evidence this dissertation encountered that, similarly to China, the US is driven towards the adoption and development of QTs by conditions of national pride. The US often argues to be home of the world's greatest universities and technology companies, which they believe have been the birthplace of the world's greatest inventors. Furthermore, the national pride of the US is also often followed by the discourse that America is a 'free country' with an unparalleled innovation ecosystem, which is very commonly used to diminish China's or other types of regime forms. As stressed by Michael Kratsios (2019) at the Global Entrepreneurship Summit (GES): *"...the United States is a Nation of thinkers, doers, inventors, and* *entrepreneurs, empowered by free markets and driven by bold ideas(…) Americans have created an ecosystem of innovation that today is the envy of the world…".*

American leaders often incorporate to their argument that America is a prosperous country because it has empowered its people to have freedom, to chase their dreams, and to create different visions of the future, *"because we live in a country where the rules make everything possible",* as President Donald Trump said (2018). However, for a country that is a consistent leader—including in the latest technologies—and that claims to have an 'unparalleled' innovation ecosystem, the biggest concern is how to maintain that leadership, that 'unique' ecosystem, that has allowed the US to retain power in times of great power competition. As stated by Michael Kratsios at this year's "America's Global Tech Leadership" event organised by the Hudson Institute (2020): *"…we have the best institutions of the world, we have the most highly cited papers in the world, we have the most vibrant venture ecosystem in the world, we have the most private sector dollars invested in these domains in the world, and the list goes on (…) and on so I think in all the metrics we continue to lead the world, the question is less about where we stack up today, but how do we maintain that leadership…".*

As the sentiment analysis suggests, national pride continues to be a key driver for the US to move forward in developing and succeeding in new technologies, including in QTs. Although the US has been an early leader and a pioneer in the field, it yet has to make progress towards the implementation and achievement of superior milestones in the field, especially if it wants to remain as a competitive actor in QTs. Considering that China, and other global competitors, are rapidly moving forward and taking the lead, the US thus cannot afford to lag behind. Accordingly, its interest in maintaining its leadership explains why the US is investing heavily in this technology. However, this may also indicate that America's national pride can also affect the pre-eminence of the US in these technologies, as its great-power rhetoric can either be taken for granted by its leaders or cause the retaliation of other international actors interested in this technology. As the Centre for a New American Security (2018) has reported, for the first time in recent history, the US may face real dangers of technological surprises in the quantum field.

(2) Diverse Workforce and industry engagement

The rapid growth of QIS and the expectation that this trajectory will continue over the next decade has led the US to rethink the country's quantum science research capabilities and workforce, as well as the Federal planning and coordination of quantum science and technology as it used by the government. Underscoring the Trump Administration's commitment to advancing QIS and QTs, the documentary evidence thus indicates that the government has elevated its work on the field and focused on major challenges that are currently being addressed with a 'whole-of-Government' response.

First, deriving from the analysis of the MAXQDA CMBs and IQM, the data evidence reveals that the US government is focused on improving and facilitating coordination both within the government and between public and private institutions to create a robust domestic ecosystem and provide worldwide leadership in this technology. This is proven in Figure 5 and Figure 9, in which, between the data from all actors, the US government holds the highest percentage of cooperation within both the scientific community and private industry. The Trump Administration is determined to increase the investment in joint QT research centres and private-public partnerships to accelerate pre-competitive quantum research and development. Furthermore, with the formation of a US Quantum Consortium, the US intends to bring together participants from the industry, academia, and government to forecast and establish consensus on needs and roadblocks, address intellectual property concerns, and streamline technology-transfer mechanisms. The documentary evidence further indicates that these efforts are mostly concentrated in the private sector as the cornerstone for establishing clear dominance in quantum computation, communication, and sensing. According to the NSOQIS (2018), coordinating efforts between the government, academia, and private industry will ensure that US leadership in QIS and QT is sustained and accelerated.

Second, data evidence shows that, in order for the US 'whole-of-Government' approach to be successful, the growth and development of a viable quantum-smart workforce capable of enacting critical elements of research and development enterprise, is crucial for ensuring the continued progress of the US in QIS and QTs. In the long-term, such workforce aims to attract and retain key talent and jobs in the US, and enable new industrial and academic efforts that rely upon QIS as a base technology (Executive Office of the President of The United States, 2018, p. 5). NSOQIS (2018) indicates that through such workforce the US will not only assure a sustained progress in this field, but also encourage, expand, and develop special (career) programmes to further enhance US leadership in quantum science and technology.

Lastly, in the view of the economic and national security importance of QIS and QTs, the US government aims to create a strong base of quantum-essential supporting technologies that are not intrinsically quantum in themselves, which is a major difference between US strategy and other countries approaches. As the QIS research and development enterprise in the US is not yet large enough to sustain an industry focused on developing and supplying all the necessary infrastructure, the American government is targeting different programmes for developing and fielding supporting technologies for QT, ranging from component technologies all the way to sophisticated fabrication and characterisation technologies. Additionally, federal agencies are exploring different mechanisms for post-quantum applications, in particular post-quantum cryptography against the threat of encryption cracking and hackable networks (Executive Office of the President of The United States, 2018)

(3) National security and military power

Is not new that the US' national security needs often drive the advancement and adoption of new technologies. The documentary evidence reveals that the US recognises QTs as a key component not just to defend itself and its interest, but to provide solutions to some of the nation's most pressing national security concerns (Executive Office of the President of The United States, 2018). Figure 4 and Figure 9 demonstrate that, between all the sectors considered, the security sector is the main sector that pushes the US to develop and adopt QTs. For instance, in the NSOQIS 2018, the US government assesses that "*advancements in quantum computing may allow for improvements in effective drug discovery, the modelling of chemical reactions to enhance corrosion-resistant materials, and most importantly, the optimisation of military logistics solutions"*.

In particular, for those military applications the US is not only considering advancing in quantum computing, but also developing quantum clocks to provide synchronised timekeeping and precision in GPS-denied environments, quantum sensors for inertial navigation, and quantum magnetometers to improve navigation information (Executive Office of the President of The United States, 2018). As the Undersecretary of Defence for Research and Engineering from the DoD, Michael D. Griffin (2020), said: "*the US is focusing on quantum technology that is going to be of use to the force in the shorter term (...) on both offensive and defensive capabilities that are plausible in the short-term for best equipping the war fighter"*. These and other opportunities in computing, networking, and sensing can play a positive role in ensuring US national security and defence interests.

Nonetheless, on its documentary data on national security and military power the US recognises that there are some challenges and possible threats that arise from these same technologies, one of which is primarily secure communications:

> one key quantum algorithm will be able to break public-key cryptography, which typically secures transactions and communications over the internet [...] while employing this algorithm is far beyond the current level of technology, the need to protect sensitive data and provide a reliable infrastructure over the long-term requires moving to 'post-quantum' or 'quantum-resistant' forms of cryptography (Executive Office of the President of The United States, 2018, p. 11).

Given the fact that China is already leading in quantum communications, and that no one knows for sure what a working quantum computer's capabilities will be, the US has thus made post-quantum cryptography and quantum computation a priority (NIST, 2019). With organisations such as the National Security Agency (NSA), the National Institute of Standards and Technology (NIST), the Defence Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), as well as national and military research laboratories, and US defence and intelligence communities, the US is determined to work across the basic science and applied technology areas to improve the understanding of what is possible with QIS and QTs, and support the necessary technological base for US capabilities (Executive Office of the President of The United States, 2018). As the technology evolves, and there is a potential for a future in which the US no longer possesses, or perhaps cannot establish clear military-technological dominance relative to great-power rival in this technology, the US is considering all possible impacts on military applications not just from US forces but from other major global powers, their dual-use capabilities, intellectual property and economic interests.

(4) International Collaboration

The data evidence reveals that science, technology, and innovation are the cornerstones of US prosperity and economic development, and given the highly interconnected world of the 21st century, the US largely depends on how American businesses operate globally and how its scientists and engineers work across borders. Considering the imperative of global recognition of American scientific and industrial enterprises, the US finds strategic partnerships a key determinant for the accelerated scientific discovery and technological applications of QTs. In addition, these partnerships are of vital importance in fostering America's economic growth, enhancing its national security, and expanding American influence.

As the US aims to maintain leadership and competitiveness in the field, these strategic partnerships with international actors will allow for the US to strengthen friendly ties with those like-minded governments and industrial partners to ensure that technologies resulting from today's investments in basic research and technological development continue to benefit the Americans, as argued in NSOQIS 2018. In addition, as Michael Kratsios (2020) pointed out on the America's Global Tech Leadership conference, the US wants to ensure that the next great technological breakthroughs are made in the West and are underpinned by Western values in order to preserve American leadership in the scientific and innovation field.

The discursive and documentary evidence suggests that if the US succeeds with these partnerships, it will not only be in an optimal position to identify and tackle worldwide quantum science and technology trends, but will also easily identify the gaps and opportunities for evolving as a leading player in the international QIS landscape. Moreover, by prioritising bilateral partnerships, the US will ensure that it continues to attract and retain the best international talent and gain access to other countries' resources, namely technology, research facilities, and QIS experts.

US' documentary and discursive evidence indicate that, in the advent of Quantum 2.0, the US faces a new age of uncertainty, in which its traditional technological predominance come across new, perhaps unprecedented challenges. By realising that the capabilities of other great powers (mostly China) are growing and matching US' abilities, and that there might be some challenges to its traditional military-technological dominance, the adoption and development of QTs have become an imperative for the US in order to preserve its status quo, its global leadership, and power.

Certainly, it is likely that US efforts and applications from quantum science and technology extend well beyond those known and documented in the open source, and the US has some potential to achieve its own 'quantum surprises' through continued advances in these revolutionary technologies. However, at a time when other nations are redoubling their efforts to invest in and support basic research in QIS and QTs, there are several limitations and concerns about the future of US innovation that could potentially shift the balance of power in favour of a new emerging leader. As Horowitz (2010, p. 11) explains, new major technological innovations can create discontinuities in international politics, ushering in the risky situations, where the actual balance of power sharply diverges.

When compared specifically with China's QIS and QT plans, the US shows a lack of high-level or long-term R&D plans and a lack of a more comprehensive approach to scientific funding, which ultimately convey China a strategic advantage over the US. China's current quantum science and technology programmes, similarly, reflect a better 'all-of-government' approach, whereas the US has been inconsistent in its support towards quantum science and technology, and the overall scientific and technological innovation field. For instance, in its quantum-related strategies, the US emphasises on expanding a viable quantum-smart workforce able to enact critical elements of research and development enterprise (Executive Office of the President of The United States, 2018). However, as announced on the 23rd of June 2020, President Donald Trump has set some restrictions to limit the entry of foreign workers into the US (Subbaraman & Witze, 2020), a move that has sparked alarms among scientists and experts concerned about the future of US scientific discoveries and industries, and that proves that there is a lack of consistency between US strategies and US government leadership. This could ultimately result in a high turnover of talented individuals, which could potentially serve China's strategic objective to develop and enhance its quantum workforce.

Equally important to note, is that the US government and military have failed to align its priorities, incentives, and time horizons with those of the scientific community and industry. Whereas commercial advances in China might be more 'readily transferred for military employment, especially through the application of its national strategy of military-civil fusion' (Kania & Costello, 2018), which historically involves a higher alignment between industry, academia, and the military, and thus leaves successful US defence innovation made in the past to slowly erode.

Given the complexities and uncertainties of QT applications and their possible effect on the balance of power and future warfare, the US faces the potential of a future in which it no longer possesses or perhaps can no longer establish a clear military-technological dominance. If it fails to maintain its leadership on this quantum race, a major paradigm shift in today's information technology environment may occur. Thus, the US imperative role has been to concentrate in finding ways to integrate these technologies where appropriate and establish new technological and operating paradigms to adapt to the potential disruptive changes they bring (Costello, 2017). This requires staying ahead of foreign efforts, monitoring their progress, and ensuring the US stays at the forefront of QTs.

4.3 European Union (EU)

The adoption and development of QTs and QIS in Europe stems from the EU's ambition to *become* a worldwide knowledge-based industrial power and technological leader. This is highlighted mostly through the sentiment analysis and the variable for analysis of international competition from the MAXQDA CMBs and IQM. In the past, Europe has missed the opportunity to capitalise on major technology trends (i.e. digital platforms) (European Commission, 2017). Nonetheless, with its Quantum Flagship Initiative (QFI)—a large-scale, long-term initiative that brings together European research institutions, industry, and public funders to expand European leadership and excellence in this field—and its Quantum Manifesto (QM), the EU aims to place and keep Europe at the forefront of Quantum 2.0, in particular with a leading position in scientific research. This sense of competitiveness accounts for almost 15 percent of EU's discursive and documentary data, mostly driven by the desire to kick-start a continent-wide quantum-driven industry and accelerate market take-up.

EU's data evidence suggests that its efforts in QIS and QTs are mostly concentrated around four distinct but interconnected application domains: communication, computing, simulation, and sensing and metrology as a whole. The flagship alone is intended to fund over 5,000 of Europe's leading QTs researchers over the next ten years, with an expected budget of EUR 1 billion (European Commission, 2018). Considered to be the most important and ambitious project, it is its long-term vision to develop a so-called 'Quantum Web' (also referred to as 'Quantum Network'), where computers, simulators and sensors are interconnected via quantum communication networks (Riedel, et al., 2019). On the corresponding time scale—which is in fact longer than the flagship's expected duration itself—the performance enhancements resulting from QTs in the EU intend to yield unprecedented computing power, guarantee data privacy and communication security, and provide ultra-high precision synchronization, measurements, and diagnostics for a range of applications available to everyone locally and in the cloud (European Commission, 2017, p. 1). Furthermore, the documentary evidence suggests that, through advances in QIS and QTs, the EU aims to ensure the development of a competitive European quantum industry that produces impressive research results available as commercial applications and disruptive technologies, making it a highly competitive player in the field. Overall, developing Europe's QT capabilities will help to create lucrative knowledge-based start-ups, stimulate the growth of SMEs and industry, and lead to long-term economic, scientific, and societal benefits for all Europeans (European Commission, 2018).

Based on the EU's QFI, QM, and speeches of top-level organisation officials, this dissertation examines various themes that shape EU's current decision-making, postures, behaviour, ambitions, and expectations into the development QIS and QT adoption:

(1) National Pride and Leadership

Europe resonates with its long tradition of excellence in research and support in scientific discoveries. Similar to China and the US, the data evidence indicates that national pride is a key driver for EU's adoption of QTs and developments in QIS. Evidenced by the sentiment analysis illustrated in the MAXQDA CMBs, the EU holds the largest percentage of 48% in national pride. However, EU's pride on the field is mainly concentrated on its scientific research excellence. Whereas, the US' and China's national pride is more focused on its industrial base, innovative ecosystem, and cultural and national background.

In particular, within its flagship initiative (2017, p. 3), the EU highlights that: *"Quantum physics was created in Europe in the first decades of the 20th century by a generation of young physicists who are now familiar names: Bohr, Planck, Einstein, Heisenberg, Schrödinger, Pauli, Dirac, Curie, De Broglie"*. After the publication of revolutionary ideas from these prominent physicists, the continent claims to still retain the largest share of academic output in the quantum field (Riedel, et al., 2019). As noted on the QFI (2017, p. 3), McKinsey's data estimates that over 50 percent of academic papers in the quantum field come from European scholars. Just in the period of 2013-2015, 2455 authors of quantum physics papers came from the EU, compared to 1913 from China and 1564 from US (Kalbe, 2016).

To date, the European Commission (EC) has demonstrated its commitment to actively support the development of QTs in order to enhance its scientific excellence in the field, especially through the accelerated development of domestic scientific collaborations across Europe, which cannot be overlooked. The documentary and discursive evidence indicates that these collaborations amongst its Member States are in fact a key component and strength of the EU's initiative, as it adds value to its unique integrated system that allows to combine and maximise the strength and flexibility from the Member States of the Union. Such collaborations not only enhance the exchange and networking of people and information across Europe, but fosters mobility and scientific discoveries across academia and industry. As the President of the EC Ursula von der Leyen has stressed continually over her speeches: *"...it is not only about parties and politics, rules or regulations, market or currencies (...) it is ultimately—and above all those things—about the European people (...) it is about Europe standing together for* *their liberty, for their values, simply for a better future…"* (European Commission, 2019). Europe through its scientific excellence and integrated ecosystem is set to kick-start a competitive European industry in QTs and position Europe as a leader in the future global industrial landscape.

(2) Sustainable Innovative Ecosystem

Europe aims to harness QTs for strengthening its industrial base and technological potential that can lead to an innovation ecosystem that is sustainable. As President von Der Leyen (2019) said: *"For years, we have invested less innovation that our competitors do, this is a huge handicap to our competitiveness and our ability to lead this quantum transformation".* To achieve its goal, the EU is thus addressing the challenges of scaling up from labs to products and services (European Quantum Flagship and European Commission, 2020), which means they intend to improve the transfer from research to physical applications. Through the contribution of all stakeholders in Europe, from research laboratories to industry and potential users of these technologies (i.e. governments), the EU intends to fulfil its goal and place Europe at the forefront of the emerging quantum industry.

Similar to the collaborations between China and the US with the academia and private industry, the EU hopes to bring together research institutions, industry, and public funders across Europe to consolidate this sustainable ecosystem. This has been widely illustrated under the MAXQDA CMBs and IQM, in which between the data from all actors, the EU holds the second highest percentage of cooperation between both the scientific community and private industry.

On the one hand, the EU hopes for research laboratories across Europe to propose new concepts and new scientific outcomes for the field. On the other hand, the European industry, having a detailed knowledge of their needs, ought to define specific use-cases in computation, communication, sensing and navigation, where QT-based products can bring new solutions or new functionalities to Europe. The governments, conversely, are responsible for setting the agenda and funding for introducing these new applications to societies as fast as possible.

However, as former European Commissioner for Digital Single Market and Vice President of the European Commission, Andrus Ansip, stressed at the Future and Emerging Technologies (FET 2017) Flagships event: *"while Europe has many world-class scientists in quantum, so far there is little industrial take-up or commercial exploitation".* This still holds true to date, as there is still a relatively smaller number of industries that are involved in the development of QTs and fewer private investors in Europe than in the US or China. The academia is thus considered the only driving force at the moment pushing technical advancements of QTs applications in the European context. This does not mean that the EU is less competitive when compared to other actors, but to some extent it has a longer way to go to stay ahead of China or the US.

Nevertheless, according to the EU's documentary and discursive data on the nature of this sustainable innovative ecosystem and the transfer from research to real quantum applications, Europe's key advantage over its competitors is its unique position to influence QTs advancements through legal means. For instance, by setting standards and legal precedents for the use of QTs, i.e. protecting its intellectual property. Similar to the use of the GDPR, the EU can force external actors to conform to the European standards. Furthermore, as investigations from the Hague Security Delta (2019) point out, there is undoubtedly a recurrent sentiment among EU stakeholders that protectionist measures should be applied to QTs, including for keeping advancements in this technology in

Europe and limiting infrastructure integration with other actors. If not, Europe's leading position in scientific research could easily erode.

(3) Quantum Talent

Deriving from the desire to become a worldwide knowledge-based industrial power and technological leader, EU's documentary evidence indicates that, as the global race for QT evolves, education is becoming one of the key factors for establishing a strategic advantage in the quantum field. As the EU Strategic Research Agenda (SRA)—that is, the 2020 thorough review on the vision and goals for the Quantum Flagship—suggests:

> In order to prepare the industry for the development of quantum technology products and services, a flow of students from science to industry is required […] it must therefore be a priority for the Member States and the EU Commission to significantly increase the number of trainees in this sector in order to meet the foreseeable demand (p. 10).

Considering that scientific research is the strength of Europe on the ongoing race for QTs, the EU thus cannot lag behind in its quantum talent. Accordingly, the EU intends to enhance its learning ecosystem that embraces the concepts of quantum physics at all levels, ranging from school level up to the working environment. This is crucial not just for a quantum-ready workforce to emerge in Europe, but for a well-informed society with knowledge and attitudes towards the acceptance of QTs (European Quantum Flagship and European Commission, 2020). Furthermore, international cooperation on scientific research is of strategic importance for the EU.

Similar to the US' intended trajectory to leverage from international cooperation with like-minded governments and industry, Europe seeks to leverage from key international partners and institutions across the globe that help identify new use-cases in which QTs will bring added value to Europe. Through such collaborations the EU hopes to benefit not only from having European students learning new skills abroad that they cannot acquire in Europe, but also to attract and retain the best talents from abroad to work and engage in world-class European research institutions. As relevant activities, Europe may also leverage from its joint education programmes, joint courses, joint PhDs, and professor exchanges (namely Erasmus+) in engineering and mathematics, including with countries such as China that have already well developed advanced quantum programmes. In the long run, these collaborative efforts will allow Europe to foster a competitive European quantum industry, endorse Europe as a global leader and further enhance European scientific leadership and excellence in quantum research, in addition to transforming the Union into a dynamic, attractive region for innovative quantum technology research (López, 2019).

(4) National Power and Competitiveness

On its documentary and discursive data, the EU recognises that the competition to control new technologies and the willingness to use them to gain an advantage over its competitors underlines the growing importance of QTs. It is for this reason that the EU is working towards the imperative of 'technological sovereignty' in areas of key strategic importance, namely quantum computation, communication, simulation, sensing and metrology. Similar to a naval flagship, coordinating the activities of a whole fleet of independent ships, Europe with its QFI aims to produce a 'Quantum Fleet' to bring together and steer the European activities in QTs. Some of the most noteworthy activities and projects supported by the QFI are the following:

- OpenSuperQ project which aims at designing, building and operating a quantum information processing system. The scale of the computer of 50-100 qubits will be among the leading platforms in the world and presumably the first one developed in Europe.

- AQTION project which focuses on the technological framework for quantum computers to solve real-world problems inaccessible to current classical computers, including computational problems in chemistry and machine learning.
- macQsimal project for developing quantum-enabled sensors with outstanding sensitivity for five key physical observables, namely magnetic fields, time, rotation, electro-magnetic radiation and gas concentration. These breakthroughs aim to firmly establish European leadership in the quantum sensor industry.
- QIA project which targets a Blueprint for a pan-European Quantum Internet by ground-breaking technological advances, culminating in the first experimental demonstration of a fully integrated stack running on a multi-node quantum network.
- iqClock project to provide major breakthroughs on telecommunication (e.g. network synchronization, traffic bandwidth, GPS free navigation), geology (e.g. underground exploration, monitoring of water tables or ice sheets), astronomy (e.g. low-frequency gravitational wave detection, radio telescope synchronization), and other fields.

These projects and activities indicate that Europe's goals in the field are very ambitious and challenging. Europe's quest to pioneer rapid and disruptive advances in QTs could potentially enhance Member States' economic and military dimensions of national power. Although individual Member States of the Union may pursue specific goals of their own in QTs, these joint initiatives demonstrate that the EU as a whole wants to compete aside with major contenders on this great power competition for QTs. In particular, if the EU succeeds in the development of a Quantum Communication Infrastructure (QCI)—that would in a first stage prepare the connection of quantum computers and sensors in a full Quantum Information Network (better known as the Quantum Web)—a competitive advantage in robust and secure communication infrastructure over the US could be achieved. This infrastructure would not only allow to protect European sovereignty and economy in the face of increasing cybersecurity challenges but also guarantee its continued development in an increasingly troubled international environment through the support of its initiative of a sustainable innovative ecosystem, which is key for the strategic autonomy of the Union, both for security-related aspects of QTs as well as for leadership on the global market (European Commission, 2019).

Overall, the EU's documentary and discursive evidence reveals that the EU is driven towards the adoption of QTs not only by its desire to become a worldwide knowledge-based industrial and technological leader in this innovative field, but, most significantly, to ensure that such technologies are not exploited with malicious intentions by great powers. While the ambitions of China and the US indicate that the adoption of QTs derives from the maximisation of power, EU's adoption thus seems to be a response to counter potential effects of QTs in the international system dynamics, including what seems that of a weaponisation of this technology and a potential shift in power.

As President von der Leyen said: *"This is an unsettled world, where too many powers only speak the language of confrontation and unilateralism ... the world needs our leadership more than ever ... to keep engaging with the world as a responsible power, to be a force for peace and for positive change"* (European Commission, 2019). This represents one of the most significant findings of this dissertation. While the US and China seek quantum hegemony and try to leverage mostly from military applications (as the documentary evidence has shown), Europe is rather interested in ensuring that such technology is deployed around the globe responsibly. The EU has thus shown a more genuine interest in becoming the shaper of a better world, where technologies are rather used to support people's security, information, and communications.

Deriving from the dimensions on national power and competitiveness, EU's data evidence suggests that Europe is close to chart a middle path between China and the US, with some limited involvement from governments and industry players (Verhagen, et al., 2019). On the one side, while China holds the largest budget for developments in QTs and its research agenda is far more broader than that of the EU's, Europe still holds a stronger global position in its specialised academic research on quantum physics, to the extent that the father of Chinese quantum information science, Pan Jianwei, came first to Europe to specialise in quantum physics at the University of Vienna and learn from prominent Austrian quantum physicist Anton Zeilinger before transforming China into a quantum superpower. On the other side, while the US has a much stronger quantum-ready industry, the EU is doubling its efforts to bring QTs out of the lab significantly faster. Furthermore, EU is far more prepare for developing specific use-cases that can maximise the benefit of quantum networks, besides seeding the growth of the necessary supply chains and providing a training ground for future quantum-aware workforce. Most importantly, as mentioned before, the EU's key advantage over its competitors is its unique position to influence QT advancements through intellectual property, more like 'technological sovereignty' in QTs. Europe has the full capacity to keep this advancements in Europe and limit infrastructure integration with other actors that intend to leverage from EU's discoveries and applications in QTs. All of these dimensions prove that Europe has still some significant elements to become a world leader in QTs and succeed in its quest to become a knowledge-based industrial power.

To sum, this dissertation applying Horowitz insights on the spread of technological innovations analysed in this section those ambitions, postures, behaviours and expectations of major global powers towards QTs. By analysing the various categories that account for the emerging ideals underpinning power projectability in the quantum field, this dissertation was able to determine which are those incentives and constraints that drive the diffusion process of this technology. From national pride to geostrategic considerations, and dimensions of national and military power, as well as presumptions of threats and capabilities, this dissertation demonstrates that all of these variables in fact play a primary role in shaping states' decision by serving as pressure points for the adoption and development of QTs.

One can understand that strategic competitions between great powers are not new. However, in the advent of new and emerging technologies, QT demonstrate a unique potential to influence the dynamics of the international system, the strategic balance of power, and future warfare. Not only does the data evidence suggests that the emergence of QTs and QIS research may transform current paradigms of military power, but QT's commercial applications may set some changes in the economic arena, where first movers that innovate and generate new ways of producing forms of power in QT can gain significant advantages and sustain their global leadership in this quantum revolution.

Although it is difficult to predict the long-term trajectories and the full potential of QTs, the spread of this technological innovation signifies the impact on the geopolitical lines and future warfare, in which: (1) China's ambition to become a world-class technology superpower may signal an eastward shift in the locus of international innovation in the near future; (2) US' pre-eminence in technology and military and economic affairs could take a swift action to regain its lead in QT and other emerging technologies and preserve its status quo; and (3) the EU as a knowledge-based and industrial leader could potentially mitigate any possible swift in power, as it is uniquely positioned to influence QTs advancements through legal means especially given the fact that the EU is collaborating with both the US and China to advance in QIS and QTs.

In particular, and as the evidence suggests, China leads in this quantum revolution. The country is not only the largest investor in the field, but it is in a unique position to benefit from first-to-market advantage that, when coupled with its manufacturing power and human capital base, will enable it to achieve and sustain a global leadership in this quantum revolution. Furthermore, the impressive quantum capabilities China holds over its adversaries can have serious implications on the future of military communications, encryption, and stealth technologies. These capabilities could potentially reset the military and intelligence balance in China's favour.

The US, conversely, could enhance the quality and number of academic institutions, venture capital investments, industrial and technological base, as well as the quality and speed of private innovation in order to regain its lead. The US was once the leader in QIS, but the lack of funding, structural and institutional issues, and lack of government coordination have reduced both the levels and consistency of support that are necessary to maintain capacity in this quantum revolution (Costello, 2017, p. 15). As the country is already challenged by the industrial might and growing human resource base of China's emergence on the world stage, the US strategic choices are limited to preserve its dominance in the industrial base, in technological innovations, and in world-class academic and research institutions or step up in its investment and overall approach to restore itself as an innovation powerhouse in QIS and QTs. Either way, it is not likely that the US will risk falling behind in this quantum revolution, nor risk being denied its role as a leading hegemonic power.

On the other hand, as the data evidence suggests, the EU could potentially mitigate any potential shift in power by preventing the 'weaponisation' of this technology and malicious intentions from both actors—although this is highly unlikely to occur as the EU has no utter knowledge of the capabilities of other countries or their full resources. The diffusion of such technologies, consequently, prove difficult to constraint. Investments in the field are likely to increase and the capacity for developing new quantum offensive and defensive capabilities prove difficult to be restrained in the near future. After all, as argued by Baldwin (1979) and Horowitz (2018), countries cannot maintain military superiority over the medium to long term without an underlying economic basis for that power.

CHAPTER 5: CONCLUSION

This dissertation studied the relationship between QT and major global powers. While prior literature on global politics and international security have studied the conditions into which technology has influenced and transformed power politics, very few existing studies have examined the role of new and emerging technologies in the dynamics of the international system, the strategic balance of power, and future warfare (Kania & Costello, 2018; Verhagen, et al., 2019; López, 2019; Horowitz, 2018). This study sought to understand and explain the issues QT raise for the traditional balance of power, international competition, and future warfare by investigating the strategic ambitions, postures, behaviours, and expectations of major global powers towards QTs. In particular, this dissertation utilised Horowitz AC theory to develop a deeper understanding on the spread of QTs, the incentives and constraints behind major global powers' decision to adopt and develop such technologies, and most importantly, the implications these technologies have on the structure of international competition, balance of power, and future warfare.

To address the research questions and objectives of this dissertation, a mixed methods approach was adopted, incorporating extensive documentary and discursive analysis based on key quantum-related strategies, initiatives, speeches, and press releases from China, the US, and the EU. The use of both documentary and discursive data, although part of the same discourse, allowed for written and spoken communication to be analysed through a combination of 'traditional' (quantitative) content analysis, based on word and phrase count, and a (qualitative) discourse analysis that focused on the language used and the contextual factors in which the documents and speeches emerged (i.e. sentiment analysis). The implementation of both methods resulted in a broad coverage of data that enabled an effective corroboration of information obtained from countries strategies and discursive data. In particular, the use of verbal communication proved to be a key determinant for this dissertation, as it revealed further information that was not initially disclosed in the documents already reviewed. Ultimately, these methods enabled a thorough investigation of the relationship between major global powers and QT advancements.

As regards to the analysis of the data, this dissertation utilised the assisted qualitative data analysis software, MAXQDA, to organise all data collected and uncover meaning and patterns of the research problem. Although the coding process was time consuming, the implementation of this software allowed much more efficient and successful working processes by saving a significant amount of time and providing a greater insight into the data used. Similarly, MAXQDA proved to be a crucial tool for the display of data, i.e. for the production of quantitative and qualitative matrices for analysis.

The adopted theoretical framework, methodology and research methods enabled to conduct an in-depth analysis of: (1) the causes that drive major global powers towards the adoption of QTs, and (2) the real meaning (reinforced by postures, behaviours, and expectations) major global powers have towards these technologies. This dissertation found that national pride, geostrategic competition, national and military power, as well as implicit assumptions of threats and capabilities, are influencing major global powers to adopt and develop these technologies. Moreover, state behaviour is pushing for the rapid advancements in QTs, as a result of pressure from actors to improve and translate quantum capabilities into a new form of power.

The data evidence from these three major global powers also indicates that much of the incentives for the adoption of QTs stem from individual specific ambitions. At the one hand, China's adoption of QTs derives from its desire to become a world-class technology superpower, a 'socialist modernised powerhouse' that can dominate on new technologies (State Council, 2016); more specifically, China wants to surpass the US and become the global high-tech leader. At the other hand, the US' adoption of QTs is driven by its ambition to preserve its global leadership and power. The US has recognised that the capabilities of other countries (mostly China) are growing and matching US ability. Furthermore, the US knows that if China succeeds, there is a potential for a future in which it can no longer possess a clear military-technological dominance. The adoption and development of QTs have thus been an imperative in order to preserve the status quo. The EU, conversely, as the leader in scientific research on the quantum field, is driven towards the adoption of QTs not only by its desire to become a worldwide knowledge-based and industrial leader, but, most significantly, to ensure that such technologies do not lead to a destructive future, including what would be the weaponisation of such technology or a shift in power towards a new world order. All of these findings point out the significant impact QTs have on the balance of power and on the geopolitical lines, in which advancements in the field could signal an eastward shift in the locus of international innovation or otherwise preserve the status quo. Ultimately, the impact is and will be defined by how countries end up using (in practice) these technologies, as well as how other countries react and determine the future trajectories of QTs. The outcome of this race will not be determined in months or years, but rather in the decades to come.

Although several significant findings were discovered, there were some limitations and concerns in conducting this study. As QTs are in their infancy stage and much of the literature in this topic is based on presently ongoing initiatives and policies, access to data was limited. It proved difficult to find valuable sources of data and materials that discuss QTs from a political or strategic perspective, rather most of the studies available in the open source relate to the technical side of QT. Moreover, as the primary source of data for this dissertation relies on countries strategies, programmes, and initiatives, there is a possibility that the data gathered may only provide a superficial answer to the research problem. Countries may reserve their right to publish sensitive or confidential information, so data may either prove overstated or understated. Based on MAXQDA output certain variables recorded a very low percentage when in fact they could possibly be one of the main factors driving countries towards the adoption of QTs. For instance, the code 'Threats' was not documented in the strategic documents of China nor the US, nonetheless these countries seem to be threatened by each other's capabilities and the impact these can have. Similarly, there is a possibility that the actors studied in this dissertation did not include factual data or depose their real intentions in QT in their strategic documents, thus the data analysed for this study may not fully portray their true ambitions and expectations on the quantum field.

Overall, the limited access of literature for QTs is a weakness for theoretical advancement in the field, nevertheless, it provides new opportunities to expand on the topic. Further research in the future could examine the possibilities afforded by advanced quantum information technologies in cybersecurity, national security, and military power. For instance, future research could study the transformational power of QTs on the most critical national security tools and tasks in current times, such as intelligence collection, solution optimisation, encryption, stealth technology, and communications. Moreover, on the broadest level and for when such technologies reach mature stages, the prospect of post-quantum international security could examine how actors will behave in cyberspace and the potential implications these can have for national security.

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