Who gets what, when, and how? An analysis of stakeholder interests and conflicts in and around Big Science

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1. Introduction

Public attention to and academic interest in Big Science has surged in recent years, among other things because some policymakers and scientists frame this type of science as a way to address some, if not all, of the great challenges of our time (Koch and Jones, 2016). In the pertinent scholarship, Big Science is most commonly defined as conventional science made big in three dimensions, namely organizations, politics, and machines (Hallonsten, 2016: 17). This definition reflects that the organization of large scientific projects requires hierarchical structures and big teams that are typically, but not always, formed and organized around large scientific instruments (Cramer et al., 2020: 10). It also indicates that large-scale research projects need substantial funding, in the multimillion- to billion-dollar class, which usually comes from the highest political level (Hackett et al., 2004: 750).

In the 1960s, when the term Big Science was first coined, it was used in a different sense. The physicist and manager of science Alvin Weinberg, for example, used the term to describe what he perceived to be a worrying development in the organization of research and development. Specifically, he argued that Big Science requires the increasing subordination of scientists at the expense of their academic freedom and individual creativity, especially if large-scale research projects are connected to the military-industrial complex (Cramer et al., 2020: 8). In Weinberg's days, Big Science did indeed have a clear military connection and was attuned to a bipolar geopolitical world order (Ulnicane, 2020: 76; Hallonsten, 2016: 5). Accordingly, "Cold War" Big Science was especially prevalent in disciplines such as physics, astronomy, and space science (Crease and Westfall, 2016).

With the end of the Cold War, however, Big Science "transformed" in two important ways (Hallonsten, 2016). First, it began to more strongly focus on "innovation-based growth, sustainability, and addressing grand challenges" (Ulnicane, 2020: 76) as well as favoring practicality and industrial participation over basic science (Westfall, 2012: 439; Crease and Westfall, 2016: 30-32). Second, Big Science became increasingly common in research fields other than astronomy, physics, and space science (Hallonsten, 2016: 6). It has, for example, found its way into disciplines such as neuroscience, biomedicine, and material science.

Both "Cold War" and "transformed" Big Science bring a plethora of different stakeholders with potentially diverging interests and expectations together for a long period of time (Hackett et al., 2004: 749; Anderson et al., 2012; Börner et al., 2021). This includes policymakers, scientists, (scientific) managers as well as local host communities. Each group has considerable, though sometimes different, stakes in Big Science. For instance, policymakers typically perceive Big Science as a means to accumulate or increase national prestige and prosperity (McCray, 2010; Krige, 2013; Riordan et al., 2015; Williams and Mauduit, 2020). Scientists, in turn, hope to shape research agendas for the coming years or decades through Big Science (Baneke, 2020: 169). Finally, local host communities are typically interested in the local socio-economic investments which Big Science may stimulate (Walker and Chinigò, 2018). These diverging interests require stakeholders to negotiate and to compromise between and among one another. In cases where this is not possible, conflicts are likely to arise in and around Big Science.

This thesis aims to shed light on how different stakeholders pursue as well as negotiate their interests within and in relation to Big Science, and to explain how this may lead to conflicts between and among stakeholders. In doing so, it contributes to a deeper understanding of stakeholder interests and conflicts which is of academic and practical relevance as such an understanding lays the groundwork for effective stakeholder and conflict management.

1.1. Literature Review

The existing scholarship on Big Science is highly heterogenous (Capshew and Rader, 1992: 5) and interdisciplinary (Rüffin, 2020: 27), with contributions coming from disciplines as diverse as science and technology studies (e.g. Mahfoud, 2021; Aicardi and Mahfoud, 2022), history (e.g. Cramer, 2020; Brookhuis, 2022), political science and international relations (e.g. Walker and Chinigò, 2018; Ulnicane, 2020; Robinson, 2020; Kaufmann et al., 2020), management and organization studies (e.g. Lambright, 2002; D'Ippolito and Rüling, 2019) as well as sociology (e.g. Hallonsten, 2016; Gastrow and Oppelt, 2018). Given the interdisciplinary nature of the Big Science literature, it comes as no surprise that not all scholars examining large-scale science projects use the same language and terminology. For example, some scholars refer to what this thesis labels as Big Science as "large-scale science projects" (Shore and Cross, 2005), "megascience" (Jacob and Hallonsten, 2012; Bodnarczuk and Hoddeson, 2008), "large-scale research infrastructures" (D'Ippolito and Rüling, 2019), "international organizations" (Zapp, 2018), or "public research institutes" (Jang and Ko, 2019). The following literature review takes this into account and provides an overview of the literature which explicitly or implicitly deals with science collaboration in the multimillion- to billion-dollar class, with the objective of identifying blind spots in the ramifying literature.

In the literature on Big Science, studies which engage in theory-building are few and far between. Most studies borrow existing mid-range theories or concepts from different disciplines to examine specific phenomena in large science collaborations. Theoretical concepts that feature prominently in the Big Science literature include but are not limited to science diplomacy (Höne and Kurbalija, 2018; Claessens, 2020; Åberg, 2021), trading zones (Lenfle and Söderlund, 2019), pork barrel politics (Hallonsten, 2016), and moral economy (McCray, 2000; Baneke, 2020). Principal–agent theory is one of the few mid-range theories that is used in the Big Science scholarship (Hallonsten, 2016). In addition, systematic comparative analyses of Big Science are hard to come by (Rüffin, 2020: 41-42). Noteworthy exceptions are two studies that look into the different pathways that facilitated the establishment of the European Organization for Nuclear Research (CERN), the International Thermonuclear Experimental Reactor (ITER) and the International Space Station (Robinson, 2019; 2020), Shrum et al.'s (2001) examination of the role of trust in 53 collaborations in physics and related sciences; as well as Traweek's (2009) and Knorr Cetina's (1999) seminal comparative studies of several physics and molecular biology laboratories in the US and Japan. Apart from these exceptions, most scholars working on Big Science have so far largely used single case studies (e.g. Hilgartner, 1995; Lambright, 2002; De Mendoza and Vara, 2006; Bodnarczuk and Hoddeson, 2008; Agrell, 2012; Westfall, 2012; Tuertscher et al., 2014; Cramer, 2017; Walker and Chinigò, 2018; Walker, 2019; Claessens, 2020; Chinigò and Walker, 2020; Aicardi and Mahfoud, 2022), a considerable portion of which are descriptive–historical in nature (e.g. Hermann et al., 1987; Velho and Pessoa Jr, 1998; De Mendoza and Vara, 2006; McCray, 2010; Hallonsten, 2011; Riordan et al., 2015; Heinze et al., 2015a; Heinze et al., 2015b; Cramer, 2017; Åberg, 2021; Brookhuis, 2022). Scholars have, for example, chronicled the (early) history of ITER (McCray, 2010; Åberg, 2021), CERN (Hermann et al., 1987), the German national research laboratory DESY (Heinze et al., 2015a; Heinze et al., 2015b), the European Synchrotron Radiation Facility (ESRF) (Cramer, 2017), the Swedish synchrotron radiation facility MAX-lab (Hallonsten, 2011), the Superconducting Super Collider (SSC) (Riordan, 2001; Riordan et al., 2015), the Laser Interferometer Gravitational-Wave Observatory (LIGO I) (Collins, 2003), the Brookhaven National Laboratory (Crease, 1999) and the US Atomic Energy Commission laboratory system (Seidel, 1986).

Four major themes dominate the literature on Big Science. First, studies on Big Science have investigated how scientists collaborate in large-scale research projects (e.g. Merz and Cetina, 1997; Traweek, 2009; D'Ippolito and Rüling, 2019; Aicardi and Mahfoud, 2022).

Focusing on the Human Brain Project (HBP), Aicardi and Mahfoud (2022), for example, investigate how scientists and science funders navigate the tensions and interactions that arise between formal and informal collaborative infrastructures within the project. They find that the formal infrastructures that were created to facilitate and structure collaboration within HBP sometimes clash with the preferences and everyday routines of researchers. D'Ippolito and Rüling (2019), in turn, examine collaboration types at the Institute Laue-Langevin, a science facility that provides one of the most intense neutron sources in the world. In doing so, they show that instrument scientists and users collaborate more or less intensely depending on, first, their knowledge and experience regarding the use of neutrons and, second, their interest in future developments and deepening the collaboration. Studies focusing on scientific collaboration in Big Science have further demonstrated that resources (e.g. Knorr Cetina, 1999; Bodnarczuk and Hoddeson, 2008; Traweek, 2009; Baneke, 2020), scientific objectives (e.g. Hilgartner, 1995; Mahfoud, 2021), work and task division (e.g. Knorr Cetina, 1999; D'Ippolito and Rüling, 2019), as well as management (e.g. Cook-Deegan, 1994; Hilgartner, 1995; Collins, 2003) are of particular interest to scientific communities and often cause conflict between and among them.

Second, Big Science studies have examined which political and scientific compromises as well as conditions facilitate the establishment of Big Science projects (e.g. Hermann et al., 1987; Wang, 1995; Kevles, 1997; Bodnarczuk and Hoddeson, 2008; McCray, 2010; Riordan et al., 2015; Panese, 2015; Claessens, 2020; Baneke, 2020; Åberg, 2021). Such studies on the politics of Big Science have shown that policymakers and scientists typically are most interested in and fight over issues like site selection, financial contributions, scientific access (on this specific issue, see also Langford and Langford, 2000; Williams and Mauduit, 2020), and procurement of goods (Hallonsten, 2014: 35). Krige (2013), for instance, describes how Germany was so adamant about hosting Europe's 300 GEV super proton synchrotron accelerator in the 1960s that it cancelled a high-level meeting to settle the accelerator's siting question at the last minute because it feared that the meeting's outcome would not be in its favor. Studying the US astronomy community of the late 1990s, McCray (2000), in turn, demonstrates that the question of scientific access can ignite fierce debates between scientists and considerably prolong the genesis of a big telescope project. Like Krige's (2013) and McCray's (2000) analyses, most studies on the politics of Big Science have predominantly focused on actors and countries of the Global North, particularly from the US and Western Europe (Velho and Pessoa Jr, 1998: 195), while neglecting to study those of the Global South.

Notable exceptions are De Mendoza and Vara's (2006; 2007) studies of Brazil's and Argentina's efforts to create Big Science facilities for experimental science between the 1960s and 1980s. In those studies, the authors argue that the process of establishing a Big Science facility is less time-consuming and controversial in authoritarian regimes because there is no need for consensus-making between "the forest of boards and committees" which are typically involved in getting Big Science off the ground in democracies (in: Hevly, 1992: 359). De Mendoza and Vara's studies indicate that in authoritarian settings it is key for scientists to convince a few central policymakers or military figures of a project to get it funded. These findings are supported by Velho and Pessoa Jr.'s (1998) study on the genesis of the synchrotron light national laboratory in Brazil. In their study, Velho and Pessoa Jr. seek to "identify similarities and differences between the experience of developing countries" and Western science nations in establishing Big Science facilities. Analyzing the synchrotron light national laboratory, they conclude that countries of the Global South promote national Big Science on similar grounds as countries of the Global North do. In both cases, Big Science aspirations are driven by a "desire to participate in the [science] game with the best possible resources to guarantee scientific leadership and prestige" (Velho and Pessoa Jr, 1998: 208). Velho and Pessoa Jr. do acknowledge, however, that proponents of the Brazilian laboratory were rather modest in their intent as they refrained from establishing a Big Science facility in a mature and costly research field like particle physics. In line with what de Mendoza and Vara (2006; 2007) argue, Velho and Pessoa Jr. hold that the genesis of the Brazilian laboratory differs in one important aspect from that of similar facilities in countries like the US or Japan. Specifically, they contend that in the latter case, a Big Science facility has to be approved by several political and scientific bodies, while "the entire decision-making process of building" the synchrotron light national laboratory in Brazil was "much less democratic" and largely driven by a few scientific and political individuals (Velho and Pessoa Jr, 1998: 209-210).

Third, studies on Big Science have explored and conceptualized the national and regional socio-economic benefits that may result from Big Science (e.g. Florio and Sirtori, 2016; Beck and Charitos, 2021; Kantor and Whalley, 2022), such as CERN (OECD, 2014), the European Extremely Large Telescope (Cunningham and Dougan, 2009), and the Square Kilometer Array (SKA) (Atkinson et al., 2017), a big astronomy project currently under construction in South Africa and Australia. A majority of studies which focus on the economic impact of Big Science investigate innovation and technology transfer processes in the development of spin-offs through and the effects of technological procurement for Big Science collaborations (e.g. Vuola and Hameri, 2006; Autio et al., 2004; Castelnovo et al., 2018; Scarrà and Piccaluga, 2020; Wareham et al., 2022). Case studies on CERN are particularly prevalent in this context (Rådberg and Löfsten, 2023). Florio et al. (2018), for instance, try to identify mechanisms which explain how Big Science can promote learning and innovation in their industrial partners. They also investigate how the Big Science–supplier relationship influences the performance of industrial contractors. To do so, Florio at al. (2018) analyze data from a survey of 669 CERN suppliers. They find that an industrial partner's performance and development improves because of its association with CERN. Florio and colleagues argue that this is the case because being associated with CERN facilitates the acquisition of technical know-how, provides access to scarce resources, and reduces uncertainties for a supplier (Florio et al., 2018: 932). Autio et al. (2004), in turn, use evidence from three case studies of companies that have collaborated with CERN and key assumptions of social network, social capital, and inter-organizational learning theories to come up with 24 propositions that explain how knowledge may spill over from Big Science to industrial companies. Like Florio at al. (2018), they underline that a company's association with CERN boosts new product and business development (p. 118).

As one of the few, Barandiaran (2015) examines to what extent international Big Science collaborations benefit a nation's scientific community. Investigating astronomy development in Chile, he finds that the country's astronomy community profited from and grew thanks to policies that fostered greater involvement of Chilean astronomers and universities in foreign astronomy projects from the 1990s onward. At the same time, Barandiaran contends that foreign scientists and institutions are the main beneficiaries of astronomy development in Chile, in part because the Chilean state caters to their needs, not to those of its own science community. According to Barandiaran, in the Global South, top-down state support for foreign science projects often directly clashes with the interests and needs of the more disadvantaged local scientific community. Broadly in line with Barandiaran's argument, Jang and Ko (2019) show that Big Science collaborations in the high-energy physics (HEP) field benefit "latecomers" like Mexico or Argentina by increasing their scientific output. At the same time, their bibliometric study of HEP "latecomer" publications indicates that an HEP latecomer's most highly cited publications typically remain the product of international collaborations within established and often Western-dominated Big Science installations.

In comparison to the national and regional impact of Big Science, its local dimension has so far been neglected. This applies to both the socio-economic effects and the perception of Big Science at the local level. Regarding the former, there are some notable exceptions. Peterson and Miller (2019), for example, have investigated the impact of the Fermi National Accelerator Laboratory on the Chicago metropolitan area. In addition, several South African scholars have examined the socio-economic impact of SKA on South Africa's Karoo region and its local host community (Walker and Chinigò, 2018; Walker, 2019; Gastrow and Oppelt, 2019; Chinigò and Walker, 2020). In doing so, they have also studied why parts of the local community resist SKA. In large part, their findings align with those of Hawaiian scholars that have examined the "why" and "how" of local opposition to the Thirty Meter Telescope (TMT) on Hawaiʻi Island (Salazar, 2014; Casumbal-Salazar, 2017; Goodyear-Kaʻōpua, 2017; Case, 2019; Kuwada and Revilla, 2020). Among other things, both strands of literature find that local opposition to Big Science is likely to emerge if community engagement is considered insufficient; if a Big Science facility is to be built on land with symbolic, ancestral, or spiritual significance; if local socio-economic benefits of a Big Science collaboration are perceived to be lacking; and/or if local communities are concerned about the environmental impact of Big Science. Stenborg and Klintman (2012) as well as Kaijser (2016) show that environmental concerns also triggered local resistance to the European Spallation Source (ESS), a multi-disciplinary research facility worth 1.8 billion euros located in Lund, Sweden.

Fourth, the Big Science literature has examined the organization and management of large science projects (e.g. Chaiy et al., 2009; Hallonsten and Heinze, 2012; Boisot, 2013; Eggleton, 2018; Merz and Sorgner, 2022). With respect to organization, most studies have focused on coordination as a central organizational challenge in Big Science. For instance, in their case study of CERN's ATLAS project, Tuertscher et al. (2014) examine how actors with diverse backgrounds collaborate to develop a complex technological system when coordination through hierarchy is not feasible. They argue that two things were central for effective coordination in ATLAS. First, Tuertscher et al. (2014) contend that a "boundary infrastructure" consisting of texts, tools, and simulation models that were transparent and accessible to all enabled collaborators to interpret and anticipate each other's actions. Second, their analysis shows that processes of contestation and justification within review panels for the respective subsystems of the ATLAS detector allowed collaborators to acquire knowledge that colleagues with a different background possessed. This knowledge, in turn, was ultimately needed to work on different subsystems in a distributed yet parallel fashion. Partly building on insights from Tuertscher et al.'s study, Lenfle and Söderlund (2019) argue that an "interlanguage"—meaning shared concepts, project management tools, and physical objects—likewise facilitates coordination in Big Science. They contend that the development of such an interlanguage is the outcome of a process which consists of five distinct phases. In phase one, the Big Science collaboration is set up, effectively creating a boundary between the organization and its environment. According to Lenfle and Söderlund (2019), this delineation is necessary for focused discussions and interactions to occur and the need for an interlanguage to materialize. Phase two is characterized by disagreements between the collaboration's experts which occur due to the collision of "thought worlds" (Dougherty, 1992: 179) or "creative abrasion" (in: Leonard-Barton and Swap, 1999). In phase three, an interlanguage slowly emerges as members of the collaboration borrow metaphors and concepts from other fields and redevelop them to suit their purposes. This process continues in phase four, during which metaphors, concepts, and artefacts from phase three are tested, revised, and re-tested. According to Lenfle and Söderlund (2019), at this stage, metaphors, concepts, and artefacts have matured to such a degree that they form coherent meaning to collaborating members, which allows them to more easily integrate their knowledge. Finally, in phase five, the interlanguage is institutionalized and "possibly reused in other" collaborations (Lenfle and Söderlund, 2019: 1731).

When it comes to the management of Big Science, studies have paid particular attention to the role of leadership, funding, communication, human resources, and national cultures (e.g. Shore and Cross, 2003; Shore and Cross, 2005). Touching on almost all of these dimensions in his comprehensive study of ITER, Claessens (2020) concludes that the political nature of this particular Big Science project caused many of its governance- and management-related challenges. In particular, he criticizes that ITER's early directors were diplomatic appointees that lacked experience in managing large-scale science collaborations. According to Collin (2003), such experience is crucial for a successful transition from Small to Big Science. In his study of LIGO I's early days, he argues that the project only became viable after an experienced scientific manager cut the size of the project and hired engineers to plan its construction and to provide realistic costing for the project.

As the literature review shows, there are three blind spots in the scholarship on Big Science. First, so far, scholars have sidelined theory-building and -comparison. Instead, they have used existing mid-range theories and concepts from other disciplines to study socio-political phenomena in large science collaborations. Second, the Big Science literature has largely focused on actors and countries of the Global North as Big Science stakeholders and has neglected to study those of the Global South. Finally, it has examined the national and regional impact of large science projects while paying comparatively little attention to the local impact and perception of Big Science.

1.2. Research Objectives

This thesis seeks to help close the blind spots that have been identified in the previous section. It is part of a broader European Research Council-funded project on the subject of "Addressing Global Challenges through International Scientific Consortia" (INSCONS). The INSCONS project aims to study the organizational dynamics of international scientific consortia and their interactions with broader scientific communities, various national stakeholders, and industry (INSCONS, 2021). According to the INSCONS project proposal, the thesis was intended to investigate the politics of international scientific consortia, broadly understood as the "processual" aspects of the formation and development of international scientific consortia in their cultural–political environment (Jong, 2018). This included interactions between consortia and various national entities, the political challenges that promoters of consortia face in reconciling national interests, governance structures, and cultural frames, as well as processes through which stakeholder groups end up on the periphery or outside of consortia. In doing so, the thesis was supposed to use detailed qualitative data that illuminates which coalitions stakeholders forge, which framings they use to promote their agendas and to contest those of others, as well as which interests stakeholders pursue during the creation and development of international scientific consortia (Jong, 2018). Finally, the thesis was intended to study the same three cases that the INSCONS project focuses on. These cases are ITER, the HBP, and an international terrestrial laser scanning group.

In what follows, the thesis remains committed to the objective of studying the politics of international scientific consortia as defined in the INSCONS proposal. Moreover, it does so by using qualitative methods. It also examines most of the case studies that the INSCONS project focuses on. At the same time, the original research subject and objectives of this thesis were slightly reinterpreted. First, international scientific consortia are reframed as Big Science collaborations, a term more commonly used in the social studies of science to refer to large and international science collaborations such as ITER and HBP. Second, the thesis pursues two research objectives that are more narrowly defined than what was initially envisioned in the INSCONS project:

1. The thesis seeks to shed light on how different stakeholders pursue and negotiate their interests within and in relation to Big Science.
2. It aims to explain how this may lead to conflicts between and among stakeholder groups.

In line with these two research objectives, chapters two, three and four, which make up the backbone of this thesis, respond to the following three research questions:

1. Which objectives do emerging powers of the Global South pursue in Big Science and under which conditions are they likely to achieve their objectives?
2. When and why does local opposition to Big Science persist?
3. How can conflict emergence in Big Science be theorized?

Each research question addresses a blind spot that has been identified in the literature review in section 1.2. Research question one, for example, explicitly focuses on emerging powers of the Global South, a stakeholder group that is often neglected but is increasingly important in Big Science due to this group's (geo)political ambition and importance as well as its growing scientific capacity. By focusing on emerging powers of the Global South, the thesis also more broadly advances the relatively recent global and postcolonial turn in disciplines that have contributed to the Big Science literature (e.g. Harding, 2011; Fan, 2012; Robinson et al., 2023). By examining local resistance to Big Science, research question two, in turn, concentrates on the under-researched local dimension and perception of Big Science projects. Research question three, finally, seeks to advance theory-building in the Big Science literature.

1.3. Theoretical Considerations

This thesis draws upon and combines a variety of existing and emerging theories and concepts of different research traditions to generate flexible and rich interpretative frameworks that speak to issues of policy and practice (Katzenstein and Sil, 2008: 110; Sil and Katzenstein, 2010: 411). In this sense, it follows eclectic modes of theorizing which are grounded in a pragmatist view of social knowledge (Friedrichs and Kratochwil, 2009: 701). Such a view contends that expanding the possibilities of dialogue between different—and at times competing—research traditions enhances intellectual progress and versatility (Katzenstein and Sil, 2008: 110). It does so by "selectively drawing upon a variety of research traditions" and "defining and exploring problems in original, new, and creative ways" (Katzenstein and Sil, 2008: 110). According to proponents of eclectic theorizing, it particularly lends itself to research "that engages, but does not fit neatly within, established research traditions" and that bears on "substantive problems of interest to both scholars and practitioners" (Sil and Katzenstein, 2010: 411-412; Sil, 2020: 441). They also argue that eclectic theorizing is a conducive approach whenever researchers aim to address problems "that are wider in scope than the more narrowly delimited problems" (Sil and Katzenstein, 2010) raised in paradigm-driven research.

All of this applies to research on Big Science, which is often policy-oriented as well as problem-driven and does not fit in well with one particular research tradition. This is why chapters two and three of this cumulative thesis engage in eclectic theorizing. Chapter two combines the concept of science diplomacy (SD), which has both material and ideational foundations, with key assumptions of rational choice institutionalism. In the pertinent literature, SD is most commonly defined as a concept that can be applied to the role of science, technology, and innovation in three dimensions of policy:

1. Science in diplomacy (SiD): Informing foreign policy objectives with scientific advice;
2. Diplomacy for science (D4S): Facilitating international science co-operation through diplomacy, and
3. Science for diplomacy (S4D): Using science co-operation to improve international relations between countries (The Royal Society and AAAS, 2010: vi).

Several SD scholars and practitioners have challenged this widely circulated SD taxonomy (e.g. Fähnrich, 2017; Rungius and Flink, 2020; Ito and Rentetzi, 2021) and have suggested alternative SD definitions. Yet most of them share the same material–ideational foundations as the one presented above, as they argue that SD is a means to seize new markets and key technologies as well as attract foreign talent and investment (Flink and Schreiterer, 2010: 669). At the same time, SD is understood to be a form of "soft power" (The Royal Society and AAAS, 2010: 11 ff.), a term that Joseph Nye coined and defined as "getting others to want what you want" through cultural attraction, ideology, and international institutions rather than through coercion (Nye, 1990: 166). In addition to the concept of SD, chapter two builds on key assumptions of rational choice institutionalism, which "seeks to shed light on the role that institutions play in the determination of social and political outcomes" (Hall and Taylor, 1996:

936). Rational choice institutionalism draws on the so-called "new economics of organization," a literature strand which underlines "the importance of property rights, rent-seeking, and transaction costs to the operation and development of institutions" (Hall and Taylor, 1996: 943). It assumes that actors have a fixed set of preferences and behave in a strategic manner to achieve their preferences (Hall and Taylor, 1996: 944-945). Moreover, rational choice institutionalism views politics as a series of collective action dilemmas, which can be defined "as instances when individuals acting to maximize the attainment of their own preferences are likely to produce an outcome that is collectively suboptimal" (Hall and Taylor, 1996: 945).

The analysis in chapter three is guided by a framework which fuses structuralist and cultural approaches to social movement emergence with the ideational concept of place attachment. The chapter specifically builds on resource mobilization, political opportunity, and framing theory. Resource mobilization theory (RMT) stresses the role of organizational structures and processes in social movement emergence and development (Rohlinger and Gentile, 2017: 11). According to this approach, "movements, if they are to be sustained for any length of time, require some form of organization" (McAdam and Scott, 2005: 6). This includes leadership, administrative structures, and resources (Freeman, 1979). Political opportunity theory (POT), in turn, argues that the broader political context, for example state institutions and other organized groups, determines which objectives as well as tactics social movement participants choose and how likely it is for them to succeed (Meyer, 2004: 127).

Both RMT and POT have been criticized for overemphasizing structures and sidelining meaning-making processes in explaining the emergence and development of collective action (Della Porta, 2020). Framing theory and the concept of place attachment, in contrast, emphasize the role of meaning-making processes in the emergence of collective action. Framing "refers to the meaning-making processes associated with the construction and interpretation of grievances, the attribution of blame, and the creation of rationale for participation" in social movements, while frames are the outcome of said meaning-making processes (Rohlinger and Gentile, 2017: 16). They tell the public what is at stake and outline the boundaries of a debate (Rohlinger and Gentile, 2017: 16). Place attachment, in turn, can be defined as the "emotional bonds between people and places" (Cass and Walker, 2009), where "place refers to space that has been given meaning through personal, group, or cultural processes" (Vorkinn and Riese, 2001: 252). The concept stems from the literature on opposition to renewable energy projects (REPs), where it is used to explain why some people object to REPs. It challenges "the notion that the not-in-my-backyard phenomenon adequately explains" opposition to REPs (Sovacool, 2009; Cass and Walker, 2009; Devine-Wright, 2009; Devine-Wright, 2005) by arguing that place-protective attitudes drive opposition to REPs whenever a project is seen as having a negative and direct impact on a place of great emotional, cultural, or symbolic importance (Devine-Wright, 2009: 432).

Bridging diverse strands of theorizing such as the ones outlined above is believed to come with three distinct advantages. First and foremost, it is argued that eclectic theorizing generates richer, fresher, and more flexible interpretative frameworks with broader explanatory scopes (Katzenstein and Sil, 2008: 111; 117). For proponents of eclectic theorizing, this broader explanatory scope compensates for the loss of parsimony that inevitably results from bridging diverse strands of theorizing. Second, proponents of eclectic theorizing contend that by transcending theoretical schools of thought researchers gain a deeper understanding of the research subject under investigation. Eclectic scholarship more generally is further believed to raise critical and socially important problems which have been sidelined by paradigm-driven research (Hemmer and Katzenstein, 2002: 577). Third and finally, due to its practical orientation, eclectic scholarship arguably speaks to both scholarly and policy debates, thus producing value beyond the academe (Katzenstein and Sil, 2008: 111).

At the same time, eclectic theorizing comes with some distinct challenges. For instance, it requires epistemological flexibility (Sil, 2000: 353) and intellectual versatility (Katzenstein and Sil, 2008: 117) to meaningfully translate and recombine theories from separate research traditions. Where such flexibility and versatility are lacking, the translation and integration of schemes and logics devised in separate research traditions may remain superficial at best or may turn out to be unsystematic and patchy at worst.

1.4. Methods and Data

As part of the INSCONS project, this thesis, including its methods of investigation, was approved by an ethics review committee. Because chapters two to four build on data from expert interviews—a form of human subject research—getting such approval was of vital importance.

Expert interviews and small-N case studies, the second main method used in this thesis, feature prominently in chapters two to four because they are generally considered useful for the in-depth investigation of complex and contemporary social phenomena which are either difficult to get access to or are relatively unexplored (Yin, 2003: 16; Gläser and Laudel, 2009: 13; Bogner et al., 2009: 2). This applies to the overarching research objectives of this thesis as stakeholder interests are difficult to uncover without getting access to the stakeholders themselves and stakeholder conflicts are a complex social phenomenon in Big Science which has so far remained relatively unexplored from a theoretical perspective.

In expert interviews, researchers interview individuals with specialized knowledge about a particular social phenomenon of interest. In doing so, they gain an in-depth and multifaceted understanding of said phenomenon. Compared to other qualitative methods, expert interviews are an efficient way to gather rich empirical data (Eisenhardt and Graebner, 2007; Bogner et al., 2009: 2). Because their objective is to collect "factual information" (Kaiser, 2014: 3; own translation), expert interviews are often less time-consuming than oral history interviews or participant observation. This particularly applies when they are semi-structured, meaning that the sequence of questions to be asked is predefined through an interview guideline. Due to their structured, yet sufficiently flexible nature, semi-structured interviews leave researchers more room to explore new themes which may come up during a conversation than structured interviews or surveys. At the same time, semi-structured interviews ensure more comparability than exploratory interviews which rarely cover similar topics across interviews (Gläser and Laudel, 2009: 144).

In this thesis, interview guidelines were drawn up in a partly deductive, partly inductive procedure. The deductive construction of the guidelines was carried out in two steps, which are typically referred to as conceptual and instrumental operationalization (Kaiser, 2014: 56-57). First, the main concepts of the theoretical framework chosen for the investigation of a particular phenomenon were operationalized. Second, the operationalized concepts were translated into broad question complexes and, later, into concrete interview questions. The theory-informed guidelines that resulted from this procedure were tested during a first round of interviews. It was also during this phase that new questions were added to the guidelines whenever interviewees brought up subjects that existing questions did not yet cover but that seemed relevant for a holistic understanding of the phenomenon under investigation. As a result of this procedure, the final guidelines included a set of inductive and deductive questions, some of which were adapted to the backgrounds of individual interview partners.

Generally, interviewees were selected based on the sampling for range and purpose strategy as well as the snowballing technique (Small, 2009). For chapters two and four, interviewees were chosen according to purposeful sampling. This means that individuals were approached that had been identified as key actors in the case studies under investigation during the literature review on the respective subject (Tuertscher et al., 2014: 1583). For chapter three, interview partners were selected using a sampling for range strategy. According to this strategy, sub-categories of the group under study are identified and interviewed (Small, 2009: 13). To cross-check whether most relevant interview partners had been identified and to find additional interviewees where a particular stakeholder's perspective was still missing, respondents were also asked to recommend other interview partners, a practice which is commonly known as snowball sampling. For each chapter, interviews were conducted until saturation was attained. This was when additional interviews contributed very little new information (Small, 2009: 27).

All interviews were transcribed verbatim. The interviews conducted for chapter four were transcribed manually using the qualitative data analysis software MAXQDA. The interviews on which chapters two and three draw were transcribed automatically with the artificial intelligence-powered software Trint. Although Trint is relatively accurate, the transcripts still had to be cleaned manually. Once this had been taken care of, each transcript was shared with the interviewee in question, except where an interview partner expressed that they were not interested in cross-checking the transcription of the interview. After this "member-checking" process (Ademolu, 2023), interview transcripts were analyzed according to Gläser and Laudel's (2009) qualitative content analysis or Deterding and Waters' (2021) flexible approach to coding.

In addition to semi-structured expert interviews, this thesis relies on small-N case studies, which are "best defined as an in-depth study of [a few] relatively bound unit[s]" (Gerring, 2004: 342). One of the primary virtues of this method is the depth of analysis it offers, with "depth" referring to "the detail, richness, completeness or the degree of variance in an outcome that is accounted for by an explanation" (Gerring, 2007: 49). Across all chapters, cases were selected according to Gerring's (2007, 2016) case selection techniques. In chapters two and four, several typical, yet most-different, cases were compared and contrasted to identify commonalities and differences between them. Such a cross-case analysis facilitates the development of intermediate, relative, as well as time- and context-bound generalizations (Khan and VanWynsberghe, 2008). In chapter three, a single case was examined. Investigating a single case bears the advantage that a researcher can explore a significant phenomenon under rare or extreme circumstances (Eisenhardt and Graebner, 2007: 27). At the same time, findings from a single case are hard to generalize beyond the specific case under investigation.

For the description and analysis of each case, data were triangulated from expert interviews and a variety of documents, including policy papers, government records, academic articles, websites, and newspaper reports. Such a strategy is generally believed to increase the reliability of the inferences made (in: Webb et al., 1999: 2).

1.5. Thesis Structure and Outline

This thesis is article-based and includes three publications that make up chapters two to four. The publications do not directly build on each other but stand on their own. By extension, this means that chapters two to four have distinct research designs and advance different arguments, thus depicting separate research projects with separate literature reviews and original data.

What links the chapters is that they explore social processes that unfold within and around Big Science. Specifically, chapters two to four advance our understanding of interest representation and conflict emergence in the context of large scientific collaborations. They do so at two different levels, with chapter two concentrating on the state level, chapter three focusing on the group level, and chapter four bringing both levels together. Considering that Big Science collaborations bring a plethora of actors from different societal spheres together for a sustained period, such a multilevel perspective is paramount to understanding social phenomena that may unfold in large science projects.

The remainder of the thesis is structured as follows. Chapter two investigates the objectives that emerging powers of the Global South like South Africa and India pursue in Big Science projects such as CERN, ITER, SKA, and the African Lightsource (AfLS). In addition, the chapter explores the conditions under which southern emerging powers are likely to achieve their objectives in Big Science collaborations. In doing so, chapter two speaks to the thesis' first research objective of examining how different stakeholders pursue and negotiate their interests within Big Science.

Chapter three examines why the kiaʻi, a group largely composed of Native Hawaiians, were able to sustain opposition to TMT, an extremely large astronomy project planned for construction on Mauna Kea, Hawaiʻi Island. By focusing on how the kiaʻi expressed their grievances and enforced their interests in the TMT controversy, chapter three addresses the thesis' first research objective, just as chapter two does.

Chapter four proposes a mechanism-based model of conflict emergence in Big Science, thus attending to the thesis' second research objective of explaining how conflicts may arise between and among stakeholders as they pursue their respective interests within as well as in relation to Big Science. By applying the model to three typical, yet most-different, case studies where conflict developed at the state and/or group level, chapter four also provides a proof of concept for its validity.

Finally, chapter five outlines the main findings and contributions that chapters two to four make to the literature on Big Science and, more broadly, to the scholarship on science, technology, and innovation. It rounds this thesis off by addressing the limitations of chapters two to four as well as by describing future avenues for research on Big Science.

1.6. Authorship Statement[1]

Chapters two and four of this thesis have been published as original research articles in *Science and Public Policy* as well as *Minerva*. In May 2024, a revised version of chapter three was accepted for publication in *Technology in Society* (see Table 1 for an overview).

Table 1: Overview of publications

Publication Title	Type of Publication	Publication Outlet	Status
Science Diplomacy from the Global South: The Case of Intergovernmental Science Organizations	Collaborative	Science and Public Policy	Accepted
Sustaining Local Opposition to Big Science: A Case Study of the Thirty Meter Telescope Controversy	Single Author	Technology in Society	Accepted
Big Science, Big Trouble? Understanding Conflict in and around Big Science Projects and Networks	Single Author	Minerva	Accepted

Chapter two was written in collaboration with five co-authors from Rwanda, India, and Germany. Given the chapter's focus on the Global South, the composition of the research team was a deliberate choice and an attempt to diversify the perspectives on the research subject. I initiated the collaboration and assembled the research team with the help of one of my co-authors based in Berlin. This co-author and the remaining collaborators agreed that the project would form part of my PhD thesis. As a result, I took a leading role in the project, which meant that I managed and coordinated the research process. In collaboration with one of my co-authors, I formulated and developed the overarching research goals of the project. Moreover, I collected, transcribed, and cleaned the interview data for the article and co-authored two of the four case studies. Finally, I created the tables for the article and edited the entire manuscript. My co-authors contributed two of the four case studies and helped write the theory, methods, and discussion sections of the paper. In a conscious attempt to make the project as inclusive as

[1] The authorship statement is based on the so-called "Contributor Roles Taxonomy" (CRediT).

possible, I invested a great deal of time and effort to get feedback on all drafts and changes from my co-authors.

Although I also aimed to write chapter three with a co-author from Hawaiʻi and reached out to several Hawaiian researchers, I was unable to find a collaborator in Hawaiʻi. As a result, chapters three and four were submitted or published as single-author articles. Accordingly, I was responsible for each step in the research and writing process.