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

Big Science requires large capital investments, excellent researchers, innovative ideas, and, whenever it revolves around large and complex instruments that are physically embedded in a local host community, said community's consent and acceptance. The stakeholders that are involved in Big Science, their potentially diverging interests, and expectations, can be hard to reconcile. To find common ground, Big Science stakeholders often have to negotiate and to compromise. Where this is not possible, stakeholder conflict is likely to arise.

Against this backdrop, the objective of this thesis was twofold. First, it aimed to shed light on how different stakeholders pursue and negotiate their interests within and in relation to Big Science. Second, it aimed to explain how this may lead to conflicts between and among stakeholder groups. To address these two broad research objectives, chapters two, three, and four raised and responded to three more narrowly defined sub-questions. In doing so, each chapter contributes in distinct ways to the existing Big Science literature and, more broadly, to recent debates in the interdisciplinary scholarship on science, technology, and innovation.

5.1. Main Findings and Contributions

Chapter two investigated the interests that countries of the Global South pursue in Big Science and the conditions under which these countries are likely to achieve their objectives in large science collaborations. The chapter drew on three different strands of literature, namely international research collaboration, science diplomacy, as well as institutionalism, and compared the participation of countries of the Global South in CERN, ITER, SKA, and AfLS. The analysis of these four case studies showed that countries of the Global South aim to achieve a multitude of scientific and political objectives in Big Science. These may range from capacity-building in S&T, through casting off political isolation to settling regional rivalries in the political and scientific realm. Moreover, the analysis demonstrated that countries of the

Global South have varying chances of attaining these objectives in Big Science, depending on their scientific community, domestic politics, industrial capacities, and, in some cases, geographic location, as well as a collaboration's institutional maturity.

The institutional maturity of a Big Science collaboration conditions which interests countries of the Global South can pursue because in established large science projects like CERN, founding members, typically from the Global North, have successfully cemented their institutional rights and privileges. Countries of the Global South are rarely among the founding members of established Big Science collaborations because when these were set up after World War Two, many countries in the Global South had not yet gained independence from Western colonial powers. In addition, few countries of the Global South had the economic or scientific capacity to participate in Big Science collaborations at that point in time. As a result, countries in the Global South often lack the institutional rights and privileges to shape important decisions in established Big Science projects. If the objective is to substantially shape a Big Science collaboration, countries of the Global South are therefore well advised to join it during its earliest stages. This increases the chance that institutional inertia has not yet set in. Chapter two shows that where it is not possible for countries of the Global South to join Big Science early on, it may still pay off for them to participate in a collaboration, as this enables these countries to contribute to cutting-edge research and to strengthen their S&T capacities.

The cross-case analysis in chapter two further demonstrated that an active and outspoken scientific community often paves the way for countries of the Global South to become members of Big Science collaborations. Scientific communities do so by strengthening a country's reputation in S&T as they get involved in Big Science collaborations on an ad hoc basis or by lobbying local and foreign policymakers as well as scientists to support the establishment of new Big Science collaborations. Continuous domestic political support and long-term national contributions, in cash and in kind, are equally important for countries of the Global South to achieve their political and scientific objectives in Big Science collaborations. As the case study of SKA demonstrated, such contributions signal commitment to other members and can be used as leverage during negotiations. However, given that many countries of the Global South face more acute political, economic, and human resource constraints than countries of the Global North, it can be difficult for them to provide the necessary in cash and in kind contributions for Big Science. For similar reasons, there are only few countries of the Global South that have the industrial capacities to take on substantial contracts for the large infrastructures that many Big Science collaborations rely on. In contrast to these scientific, industrial, and political capacities which are needed for almost all large science projects, a country's geographic location only comes into play if a Big Science collaboration has specific climatic or environmental requirements. This is typically the case for astronomy projects, as these tend to work best in high altitudes as well as under stable, dry, and cold climatic conditions.

Chapter two contributes to the Big Science literature in two ways. First, it adds a comparative perspective to the stock of predominantly single case studies of Big Science. Second, it explicitly focuses on emerging powers of the Global South, a stakeholder group that is surprisingly often neglected in the literature on large science collaborations despite the fact that in recent years other disciplines have paid increasing attention to countries such as China, Brazil, and Indonesia due to their growing economic capabilities and (geo)political ambitions. By focusing on emerging powers of the Global South, the chapter also advances a relatively recent global and postcolonial turn in the broader science, technology, and innovation scholarship. The chapter's focus on the Global South is, for example, in line with an emerging research agenda in the field of science and technology studies that challenges "science and technology perspectives developed chiefly in the Global North" (Rajão et al., 2014) by investigating key science policy concepts from a Global South perspective (Wakunuma et al., 2021), critically questioning the role of technology in development cooperation (Fejerskov, 2017), and examining processes of technology translation in the Global South (Lu and Qiu, 2023). Chapter two's explicit focus on emerging powers of the Global South further responds to recent calls in the SD scholarship to shift the focus from the SD capacities, experiences, and practices of the Global North to those of the Global South (e.g. Polejack et al., 2022). In line with such calls but going beyond the single case study design that is prevalent in the burgeoning literature on southern SD (e.g. Echeverría King et al., 2021; Su and Mayer, 2018), chapter two contributes a comparative analysis of how emerging powers of the Global South may use S&T to advance (foreign) policy objectives in the context of Big Science.

Some of the chapter's findings complement those of existing studies which investigate how southern actors participate in Big Science collaborations or establish their own large science projects. For instance, in line with what Jang and Ko (2019) as well as Barandiaran (2015) argue, chapter two indicates that political, economic, and scientific asymmetries between the Global North and South continue to shape Big Science collaborations to this day. This finding largely reflects Barandiaran's (2015) argument that over long stretches of the twentieth century the needs and desires of foreign science communities and institutions dictated astronomy development in Chile. It also resonates with Jang and Ko's (2019) finding that countries of the Global South still depend on northern collaboration and Big Science facilities to produce high impact publications. However, on a more positive note, and in accordance with Jang and Ko's (2019) as well as Barandiaran's (2015) studies, chapter two also showed that countries of the Global South generally profit from participating in Big Science collaborations because, at a minimum, their scientists are involved in and exposed to cutting-edge research. Finally, the chapter adds new insights to existing Big Science studies because it outlines the specific conditions under which countries of the Global South can first maximize their benefits from Big Science and second, take on a leadership position in such collaborations. In doing so, chapter two provides value beyond the academe, as the policy implications that are drawn from its findings equip practitioners with pragmatic recommendations.

Chapter three examined when and why local resistance to Big Science persists. It did so by investigating why a group largely composed of Native Hawaiians was able to sustain opposition to TMT when local resistance to Big Science is typically short-lived. Using social movement theory and the concept of place attachment, the chapter found that six factors were decisive for the resilience of opposition. These six factors were: multi-generational leaderful organization, grassroots resources, versatile tactics, anti-science counterframing, local and national political opportunity, as well as place attachment-driven commitment.

The chapter argued that multi-generational support was essential to sustain local opposition to TMT because different generations of activists with different skillsets, knowledge, and experience facilitated effective task division over time. Younger activists, for example, were able to publicize local opposition on social media, while older generations shaped strategies by sharing their knowledge of which tactics had proven successful in previous Hawaiian struggles. Having several leaders was crucial for a similar reason. Specifically, chapter three contended that leaderful organization enabled the effective distribution of responsibilities among a group of individuals who had the willingness, capacities, and skills to take on leadership tasks. Over time, this organizational approach ensured that leaders did not burn out.

Chapter three also made the point that sustained local opposition would not have been possible without a continuous flow of tangible and intangible grassroots resources. This included but was not limited to human capital, time, funding, clothes, and food. Such resources enabled activists to engage in and apply a range of different tactics throughout their struggle. The strategy of combining tactics such as legal challenges, non-violent frontline action, and social media campaigning significantly stalled TMT's development and helped activists to raise awareness of their struggle. Particularly, campaigns on social media helped TMT opponents to recruit new activists and gain additional supporters, both of which were needed to sustain activities on and off Mauna Kea.

Another reason why local opposition persisted was that activists successfully framed the TMT controversy as a multidimensional issue, in which not science itself but the research practices and ethics of "mainstream" science were up for debate. Making this distinction in framing the TMT controversy was crucial for activists because it helped them to counter popular media frames which presented the issue as one of "science vs. religion" and portrayed activists as being anti-science. Criticizing "mainstream" science for not honoring basic research practices and ethics like getting (indigenous) consent for TMT instead of questioning science per se was also key because it enabled activists to cultivate legitimacy while opposing a big scientific project of a type that is typically considered beneficial. Moreover, activists succeeded in sustaining momentum for their struggle because the local and broader political context in the US were conducive to it. The chapter argued that at the national level, efforts to protect a place of great cultural, ancestral, and spiritual significance to an indigenous population resonated with a greater awareness of indigenous (land) rights. Locally, collective action persisted because Hawaiians in favor of TMT were not as well organized and media-savvy as those that were against it. In addition, pro-TMT groups experienced considerable pushback from some of the community members that opposed the project. Ultimately, this pushback led supporters to keep their opinions to themselves. As a result, the messages of TMT opponents remained mostly unchallenged over time. Finally, and most importantly, chapter three argued that local opposition to TMT persisted because activists were deeply committed to preventing further astronomy development on Mauna Kea. To a large extent, this commitment was driven by a strong ancestral, cultural, and spiritual attachment to the mountain and its unique flora and fauna.

The chapter contributes to the literature on local resistance to Big Science, which has so far either concentrated on opposition from non-marginalized local communities (e.g. Stenborg and Klintman, 2012; Kaijser, 2016) or investigated rather short-lived local opposition (e.g. Walker and Chinigò, 2018; Chinigò and Walker, 2020). Chapter three adds to these studies as it reveals the conditions under which a marginalized host community succeeds in sustaining opposition to Big Science. In doing so, it also provides insights into the why and how of local opposition. For instance, as other studies have argued, chapter three indicates that a (perceived) lack of local engagement and benefits, a troubled history of land dispossession, environmental concerns, and diverging ontologies may trigger opposition to Big Science (cf. Kaijser, 2016; Walker and Chinigò, 2018). The chapter also showed that TMT opponents raised their concerns during public consultations and amplified their claims via (social) media, just as local environmental opponents to ESS did (Kaijser, 2016: 52).

Chapter four, lastly, proposed a theoretical model of conflict emergence in distributed and centralized Big Science to address the question of why and how conflicts emerge in such science collaborations. To do so, the model drew on insights from the interdisciplinary literature on science collaboration and Big Science as well as scholarship on SAFs. Five mechanisms—attribution of threat or opportunity, mobilization of resources, coalition-building, boundary deactivation, and innovative action—work as a link between conflict cause and outcome. The model holds that an imminent or executed decision affecting or concerning a major component of a Big Science collaboration typically leads to two reactions among stakeholders: it is perceived either as a threat or as an opportunity. In either case, stakeholders are likely to mobilize their resources and to build coalitions to defend or push their respective agenda. Building such coalitions, in turn, may require stakeholders to reach across the boundary of their own field. Once strong coalitions exist, stakeholders push their causes through innovative action which consists of disruptive tactics. These tactics break with previous conventions within a particular field or create moments of genuine surprise and accelerate conflict, as they enable stakeholders to interfere with each other's objectives.

To provide a proof of concept for the model, the chapter traced its mechanisms in ITER, HBP, and TMT, three Big Science collaborations which have experienced at least one conflictual episode. In all three cases, the model helped to explain why and how conflict emerged. The cross-case analysis in chapter four moreover showed that the tactics stakeholders revert to during conflictual episodes are characterized by a high degree of disruptiveness as each tactic broke with a previous convention in a field or created genuine moments of surprise. At the same time, the chapter demonstrated that there is variation across cases. First, the analysis uncovered that the resources stakeholders use to push their agenda may differ depending on whether conflict develops between communities and/or states. For example, in the case of ITER, political decision-makers mainly capitalized on their socio-economic resources. In the cases of HBP and TMT, in contrast, scientific and local communities leveraged their social networks to further their interests. Second, the cross-case comparison showed that conflict emergence may vary on a temporal dimension. Specifically, the analysis revealed that conflicts which are triggered by an imminent decision unfold more slowly than conflicts which are caused by a decision which has already been executed or is about to be made. Third, chapter four indicated that the mechanism of boundary deactivation only plays a role when conflict emerges between or among communities. This could indicate that scientific and local stakeholder groups are more reliant on forging coalitions with actors outside their field than political stakeholders.

Like chapter two, chapter four adds to the stock of existing Big Science literature in two respects. First, it contributes a comparative perspective on Big Science, which, so far, is rather rare in the pertinent literature. Second, by proposing a model of conflict emergence in and around large science collaborations, chapter four adds to theory-building on Big Science. Such theory-building has so far largely been neglected in the scholarship on Big Science as most studies use at best existing mid-range theories or concepts to examine large science collaborations. Many of these theories and concepts are borrowed from other disciplines, for example from political science, sociology, or economics. 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). Contrary to these theories, which were tried and tested in other disciplines before they were transferred to the Big Science literature, chapter four proposes a model that builds on said literature and has specifically been developed to understand a recurring phenomenon in large science collaborations.

Taken together, the chapters demonstrate that, in contrast to conventional science, Big Science carries significant symbolism for the involved stakeholders. Unsurprisingly, it symbolizes different things to different actors. As the case study of the diplomatic negotiations for ITER in chapter four and the enshrinement of the principle of fair return in the SKAO Convention in chapter two have shown, large science projects often epitomize “real money” to policymakers (Stichweh, 2013: 144), as Big Science typically gives a region or nation a competitive advantage in an increasingly interconnected knowledge economy. For scientists, Big Science may symbolize one of two things, depending on whether researchers expect to financially profit from the establishment of a large scientific project or not. As the case study of the HBP controversy in chapter four and TIO’s justification for building TMT on Mauna Kea indicate, large science projects often exemplify frontier research to scientists that profit from or rely on Big Science for their experiments. The analysis of the HBP controversy also demonstrates that scientists who are not benefitting from or do not need ever bigger science projects tend to equate Big Science with the downfall of "small science." For them, Big Science represents a kind of "coup d'état" of one discipline against many others because it ties scarce resources up in one single project (Stichweh, 2013: 144). Finally, to local host communities, Big Science is typically a symbol of the globalized knowledge economy. As the literature review on local resistance in chapter three has demonstrated, in marginalized contexts like South Africa's Karoo region or Hawai'i Island, Big Science often epitomizes the shortcomings of the knowledge economy. These include but are not limited to the (perceived) devaluation of unskilled labor as well as a disregard for other forms of knowledge.

5.2. Limitations and Future Research

From a methods point of view, this thesis has two limitations which should inform future research on Big Science. First, it relies entirely on qualitative methods and data, as do most Big Science studies (for an exception, see: Vincenzi, 2022). Given the exploratory character of chapters two to four, a qualitative research design was an adequate choice. Future studies on Big Science, however, should move beyond an exclusive focus on qualitative methods, for example by using mixed methods designs such as "nested analysis," as proposed by Evan Lieberman (2005), or a variant of qualitative comparative analysis (QCA) (Rihoux and Ragin, 2009; Berg-Schlosser et al., 2009). Typical for mixed methods approaches is a triangulation of quantitative and qualitative methods. Scholars have argued that mixed methods designs increase transparency (O'Cathain et al., 2010) and validity (Pickel, 2009), "give a deeper, broader, and more illustrative description of the phenomenon" under investigation (Hurmerinta-Peltomäki and Nummela, 2006: 452), and, most importantly, are more robust because in such a method mix one method can compensate for another's weaknesses (Pickel, 2009). The technique of QCA, in turn, allows researchers to combine the benefits of quantitative and qualitative methodologies although as a research technique it cannot be fully situated in one or the other (Buche and Carstensen, 2009: 65). QCA "offers procedures for the systematic comparison of case study material in a small- or medium-N design" (Thomann, 2020: 259), enabling researchers to merge the "intensiveness of case-oriented research strategies and the extensiveness of variable-oriented approaches in a single framework" (Ragin et al., 2003: 323). Considering that the objects of interest to Big Science scholars and practitioners are often "naturally" limited in number, the technique of QCA lends itself to the study of large science collaborations. On the one hand, its ability to produce "empirically well-grounded, context-sensitive evidence" (Thomann, 2020: 259) resonates with the tradition of descriptive–historical Big Science studies. On the other hand, it stimulates systematic comparative approaches and middle-range generalizations which are so far largely lacking in the literature on Big Science.

Second, as indicated in section 1.5., some of the methods used in this thesis come with distinct drawbacks. The findings from small-N case studies, for example, are difficult to generalize. Where, as in chapter three, a single case is used, it is virtually impossible to generalize findings beyond the case under investigation. For cross-case analyses, as they were conducted in chapters two and four, one can at most generate intermediate, relative, as well as time- and context-bound generalizations (Khan and VanWynsberghe, 2008). Large(r) case comparisons, ideally based on bigger data sets, are needed to confirm, refine, extend, or refute the findings of this thesis. Given the above-discussed advantages of QCA, it might prove useful in this context. In cases where large case comparisons draw on expert interviews, they should aim for maximal diversity in terms of an interviewee's profile. Although this was the objective of chapters two to four, it was difficult to balance all stakeholder perspectives. It proved particularly difficult to find interview partners from East and South Asia for chapters two and four, possibly because of cultural differences. In the case of chapter three, it was generally challenging to establish contact with potential interview partners. During the field work for chapter three, potential interviewees were hesitant to speak with a community outsider and preferred other means of communication over email. As a result of these difficulties, the chapters may overemphasize some perspectives while sidelining others.

Keeping these methodological considerations in mind, future studies on Big Science could explore a variety of questions that remain unexplored in this thesis. Many of these questions emerged from conversations or written exchanges that I had with interviewees after sharing my published or draft articles. For instance, when providing feedback on chapter two, a proponent of AfLS underlined that a former scientist-turned-union leader played a pivotal role in getting SKA to South Africa. This made me wonder what role individual actors, especially scientific ones, generally play in getting Big Science onto the agendas of policymakers and how exactly scientific communities promote the establishment of a large scientific project. So far, the pertinent scholarship has largely neglected to study the intricacies of Big Science policy agenda-setting and has simply asserted that scientists engage in some form of "lobbying" (Hallonsten, 2014) and "maneuvering" (Modic and Feldman, 2017) to put a large scientific project that they want to get funded on the map. Studies that investigate the specific mechanisms through which scientific actors promote Big Science could help fill this blind spot.

A former EU policymaker responsible for the HBP, in turn, drew my attention to the role that certain personality traits in Big Science researchers and managers may play in the emergence of conflict, after I had shared the published version of chapter four with him. Previous research on Big Science indicates that charisma, for example, can be a double-edged sword because it is on the one hand, seen as a prerequisite to attract funding for and establish a leadership structure in a large science project. On the other hand, an increased focus on a single or a few charismatic researchers in Big Science may leave other renowned scientists that are also involved in the collaboration feeling frustrated and envious. Further research is needed to grasp whether and how certain personality traits influence conflicts in Big Science. Such research would tie in with recent attempts to investigate the effect of certain behaviors, for example self-interestedness, on scientific collaboration (Ngwenya and Boshoff, 2023) and could potentially also clarify whether Shrum et al.'s (2001) claim that interpersonal conflicts are unlikely to affect an entire science collaboration holds. Finally, after having read a draft version of chapter three, an astronomer I had interviewed for the paper argued that local resistance to the TMT was "more about creating a sense of mutual identity than opposing a telescope project." While my research indicates that the movement to protect Mauna Kea can indeed be interpreted as a "second" Hawaiian Renaissance, it also clearly shows that science and its (perceived) lack of local engagement and benefit-sharing played a considerable role in the TMT controversy. The interviewee's comment thus highlights the need to further sensitize scientists, particularly those that are embedded in marginalized communities, to the importance of local engagement and benefit-sharing, as well as practices of participatory research (Atalay, 2012) and community review (Liboiron, 2021).