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Envisioning a "science diplomacy 2.0": on data, global challenges, and multi-layered networks

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The term "science diplomacy" broadly identifies interactions between scientific and foreign policy communities connected to the promotion of international scientific exchanges (also as a way to establish constructive relations between countries), and the provision of scientific advice on issues of relevance to more than one nation. Science diplomacy initiatives have been positively portrayed by practitioners, while recent scholarship has underscored the need for these actions to more directly address social and global challenges. In what follows we sketch the contours of a data-driven "science diplomacy 2.0" that could actually be seen as more directly tackling these challenges in two important ways. First, we outline a multi-layered approach that integrates data and meta-data from various disciplines in order to promote greater awareness about what kind of research should actually be prioritized in science diplomacy actions. Second, we argue for the creation of responsible innovation observatories for operationalizing such a methodology at both national and global levels.

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As advanced societies become more reliant on expert advice, its administrators increasingly look for scientists to offer solutions to complex global challenges (e.g., climate change, food security, poverty, energy consumption, nuclear disarmament, and more recently a pandemic). In turn, practitioners, in Europe and elsewhere, underline the merits of "science diplomacy" as a device that could bring them closer to addressing these global societal issues (Gluckman et al., 2017). In particular, they underscore that the promotion of scientific exchanges, and of scientific collaborations across borders, can stimulate both innovative research capable to tackle these issues, and to establish constructive relations between nations (Fedoroff, 2009; Royal Society/AAAS, 2010; Ruffini, 2017, p. 11).

Scholars have been less enthusiastic, however. They stress that the concept of science diplomacy is still in a "fluid state" and its practice does not offer a single and ready-made approach. In particular, its origins have yet to be comprehensively explored (Turchetti et al., 2020) and its present adoption does not clarify enough about how it concretely translates into science policy actions (Flink and Schreiterer, 2010) or how it brings scientists and diplomats into constructive relations (Fähnrich, 2015). The science diplomacy discourse has been dubbed as "sensationalist" as it promises a great deal more than what it actually demonstrates to deliver (Flink, 2020).

So can science diplomacy *really* be effective in tackling global challenges, and if that is the case, what would make it more successful? Recent scholarly work has put considerable emphasis on the "relational" aspect of science diplomacy, and especially the merits of better coordinating at strategic, operational and support levels specific actions within and outside Europe (Van Langenhove, 2016). A paper currently circulating identifies more interpersonal measures (mainly applicable to Europe but elsewhere too), including strengthening a dialog between stakeholders through meta-governance structures allowing bringing "actors together" in a reflexive mode, i.e., "to let them reflect on and co-construct their positions, different truths, norms and values, concerns and interests" (Aukes et al., 2019). While these approaches focussing on coordination have merits, it is equally appropriate to consider whether *specific actions* could further define science diplomacy to direct decision-makers in charge of developing national policies and international negotiations centered on better investments in international scientific collaborations. From within the scientific community, the general answer is often too simplistic, claiming that *an* investment in truly original science is always beneficial (Haynes, 2018). In contrast with this view, specific policies and strategies that demonstrate these societal and global impacts of novel research are not always easy to elaborate especially given that (responsible) research and innovation is perceived differently in different national contexts (Doezema et al., 2019) and evidence of societal impact is often asserted rather than truly demonstrated (Kuhlmann and Rip, 2018; Flink and Kaldewey, 2018).

In this article, we sketch instead tangible measures that could potentially make science diplomacy interactions more effective at local and global levels. In particular, we look at the global circulation and integration of scientific data to suggest a key area for improvement in shaping a data-driven "science diplomacy 2.0." Data are undoubtedly at the center of many studies, but most focus on their availability. In contrast, in this paper we focus on their integration, especially as data and "meta-data". Sets of data about datasets (or "meta-data") provide critical information often disregarded in the literature. One important exception is a recent article (Özdemir et al., 2014) that connects "meta"-data and global issues claiming that meta-data are decisive in better harmonizing the production of new knowledge to responsible innovation through meta-data-oriented studies of social priorities. Science diplomacy, Özdemir et al. argue further, should thus be mobilized to propel setting up of "innovation observatories", responsible for meta-data production.

This paper draws on this proposal to more concretely outline the integrated production of (meta-)data through science diplomacy with the ambition of providing the relevant policy-making organizations, especially at European level, with ideas for future actions. In particular, we discuss how a "science diplomacy 2.0" should not only promote the establishment of responsible innovation observatories, but also equip them with personnel endorsing a multi-layered approach operationalizing data integration. In this way the observatories would also feedback useful information about further investments in international scientific collaboration. We conclude that science diplomacy should lead to more investments in interdisciplinary approaches combining "hard" and social sciences.

Science diplomacy and responsible innovation

In order to address the question of whether science diplomacy could more consistently align the circulation of new data to global challenges and social demands, it is first necessary to consider what science diplomacy actually entails. The relevant literature points towards synergies that the interactions between scientific and foreign policy communities can produce, from the provision of advice on international issues with a scientific component (on environment, nuclear disarmament, etc.), to the elaboration of exchanges and international collaborative projects as a way to establish positive, constructive relations between countries. The underlying assumption in this literature is that all the stakeholders involved will benefit from science diplomacy initiatives; countries will produce relations that are more cordial, science will advance and through that advancement the society at large will benefit too (see Royal Society/AAAS, 2010). For instance Jorge-Pastrana et al. (2018) have recently documented the strengthening of relations between the U.S. and Cuba after years of tensions through the signing of a Memorandum of Understanding between the American Association for the Advancement of Science and the Cuban Academy of Sciences. It notably established an important collaboration in scientific and medical research, and especially in the search for treatments of epidemic diseases. The outcome of exercises such as this one would thus seem at first sight a "win-win" option in which scientists, decision-makers and the society at large benefit from the "science diplomacy" initiative. Gual Soler and McGrath (2017) also report that a large international collaborative project such as the Square Kilometer Array (SKA) in South Africa envisages a number of important social benefits for African countries including "to develop human capital, bring about local and regional innovation and expand capacity for data science." However, while the SKA's political and human capital benefits cannot be underestimated, there is no specific analysis showing the data put together in the collaborative exercise to have more societal impacts than other scientific datasets.

Moreover, the study of past science diplomacy exercises, provides a more comprehensive understanding of these exercises' progeny and underlying ambitions. While the historical study of science diplomacy is still in its infancy, it appears that many past schemes aimed instead at strengthening bilateral and multilateral relations thus giving precedence to initiatives that would contribute to propel them, whether socially oriented or not (Turchetti et al., 2020). The uses of science diplomacy during key periods in recent history, such as the Cold War, led to particularly problematic schemes stimulating scientific exchanges with the view of securing control over foreign science programmes and resources, or using science diplomacy projects as a vehicle for covert intelligence-gathering and espionage missions (see Smith III, 2014; Adamson, 2016, 2017; Adamson and Turchetti, 2020). They also aimed to foster political allegiance to hegemonic countries (hence within the realm of colonial and imperial projects) through the device of scientific and technological collaboration (see Krige, 2006; Wolfe, 2018). On the whole, new studies are now showing that the current science diplomats' ancestors used the promotion of scientific exchanges as a way to generate or extend asymmetrical power relations across borders and continents.

This (still unfolding) historical study adds to a number of critical reviews emphasizing how the practitioners' enthusiastic adoption of science diplomacy as a rhetorical device has led them to overlook some of its problematic features, including that it encompasses a wide spectrum of different (and competing at times) initiatives (Flink and Schreiterer, 2010) and takes for granted the constructive, positive nature of the dialog between scientists and diplomats (Fähnrich, 2015; Ruffini, 2017; Kaltofen and Acuto, 2018). Science diplomacy literature also does not provide sufficient indications for decision-makers with regards to approaching international negotiations, especially in the realm of scientific collaborations.

To make science diplomacy a force for change, at the global level, it is thus important that we first acknowledge its historical legacy and present problematic conceptualization. We should also recognize that directing science diplomacy towards societal and global challenges would represent a paradigmatic shift in foreign relations rather than something further extending past and present science diplomacy actions. In particular, we would need to consider how to instil new ambitions in science diplomacy schemes and practices at the levels of individual administrations, bilateral collaborations and multilateral agreements.

What models of positive engagement can be taken as example? The EU has recently sponsored important projects such as InsSciDE and S4D4C paving the way to a greater understanding of the science diplomacy phenomenon through collaborative engagements across European borders and disciplines. It is clearly decisive to their success as EU-sponsored collective endeavors that critical awareness in individual and joint analyses prevails over simplistic or hagiographic descriptions of a complex phenomenon.[1]

We also see recent EU science diplomacy schemes to have promise in so far as, taking stock from the experience of multilateral European collaboration in science and technology, seek to open this collaboration to non-European countries thus breaking up with the hegemonic model distinctive of the Cold War period (see, for instance, Moedas, 2016). We also commend initiatives, such as that for a Commission exploring the history of science, technology and diplomacy under the aegis of the Division of History of Science and Technology of the International Union of History and Philosophy of Science and Technology, seeking to provide a perspective on science diplomacy from non-"Western" perspectives and viewpoints.[2] We are also appreciative of "bottom-up" approaches in which national administrations echo in their initiatives the propositions set forward by the scientists themselves, especially when novel studies align to their activism thus combining genuine research interests to grassroots political projects for social change. For example, some statisticians have recently envisaged the merits of a "statactivist" ("statistical activism") approaches in which the "use [of] numbers, measurements and indicators" informs "collective action" (Erickson et al., 2020). These forms of political engagement, when applied to the scientists' involvement in the international arena, offer effective solutions, since they do not prioritize an alignment of national and supra-national interests; they configure instead efforts to transcend a national agenda in light of social and global needs.

The recently published *Madrid Declaration on Science Diplomacy* has extended this ambition to re-think about the foundations of science diplomacy reiterating that while it "has long been a tool to develop bilateral and multilateral relationships, [its] definition and applications […] broadened considerably in recent years. This conceptual broadening coincides with the growing understanding that science and technology underpin so many of the challenges and opportunities that current societies face, whether as a driver or a potential solution." The declaration was equally explicit in aligning this ambition to global challenges as recently configured in the UN context; namely to "facilitate the identification of common global challenges" especially through "efforts to achieve the 'Sustainable Development Goals'" ("The Madrid Declaration on Science Diplomacy", 2019; see also United Nations, 2020).

In what follows, we identify data circulation and integration as key items in this transformation of the science diplomacy device. Data have not regularly featured in science diplomacy studies and only fairly recently have come to occupy a space in the analysis of how to address societal and global challenges. The importance of promoting opportunities for scientific research that is socially desirable and undertaken with public interest in mind is traditionally reiterated in "responsible innovation" analyses (for an overview see Stilgoe et al., 2013). Moreover, the study of these opportunities has led to consider mainly the *production* of scientific data in laboratories and fieldwork, rather than its *circulation* and *integration*. So for instance late 1960s scholarly literature emphasized how pressure from industrial concerns (e.g., Ravetz, 1971) or the military (e.g., Forman, 1987) warped scientific production away from social ambitions setting priorities in exploring new research issues and themes. The debate on the production of scientific knowledge overlapped that on the development too, with many scholars in Latin America debating if in order for science to address societal issues it was necessary to move beyond a Western model of knowledge production or applying the same model in different ways (Vasen, 2016).

From the 1980s onwards there has been a significant shift in emphasis in scholarly analyses from knowledge production to knowledge circulation. The spreading of information technologies (and the internet) has focussed the attention of many researchers to the centrality of data circulation and integration to responsible innovation discourses. The main effect of the growing interconnectedness of distant places was to reconsider social and global needs in terms of access to scientific data produced elsewhere. It is a turn that has informed many fields of research, also paving the way to the development of "transnational" and "global" studies (see for instance Iriye, 2013).

Notably, the next generation of scholars propounding the need for responsible innovation focussed on how regions and nations can gain access to scientific datasets, and if this access can actually be of importance in shaping societal and developmental challenges. One key catalyst for this analysis was the rise of Open Access (Suber, 2012), and the emergence of the Open Science movement (Vicente-Saez and Martinez-Fuentes, 2018). As recently noted in a UN document "the basic and applied sciences in particular, in addition to being central in our daily lives, are the main triggers of technological innovations […] In this context, it is essential that science and technology be rendered more accessible worldwide, in both training and in practice" (through open access, open science and open data initiatives) (UNESCO, 2015).

In light of this shift in emphasis from production to circulation, it would appear desirable for newly designed science diplomacy schemes to address issues regarding data access and integration at global and regional levels, while the connections between the Open Science movement and science diplomacy has so far been very weak.[3] In what follows we focus on how science diplomacy could have an impact on the circulation of scientific data.

From data to meta-data (and back)

We typically refer to data as information or knowledge organized in some suitable form, initially collected as "raw", and then processed to elaborate theories, principles and products. Data are inevitably at the core of scientific research as scientists delve to collect, elaborate and use datasets accordingly to their needs. Since the late twentieth century, datasets have become so large that we have even started to adopt the term "big data." Big data are relevant to a number of scientific issues regarding the natural world on things as different as the structure of the DNA and the structure of oceans and mountains (Aronova et al., 2017). According to a report of the International Data Corporation what makes "big data" markedly different from traditional datasets is the so-called four Vs: volume, velocity, variety, and veracity; all elements of novelty that compel -at times- to elaborate new processing practices and techniques, which also become themselves useful knowledge in interpreting complex scientific phenomena (Gantz and Reinsel, 2011). The availability of these large datasets thus becomes critical to address a number of research tasks, especially (but not only) in the environmental field. It was recently shown, for instance, that scientific assessments on ecological impacts of oil spills are becoming increasingly reliant on access to datasets of various kinds (Reichman et al., 2011).

This raises the issue of accessibility to (big) data, which has even led to the development of a new "data" diplomacy concerned with negotiating access. For instance, a recent report resulting from a European project defines data diplomacy in terms of using big data as a new tool for diplomacy, as a defining topic in the diplomatic agenda, and as an element hanging the environment in which diplomats operate (Jacobson et al., 2018). Boyd et al. (2019) have argued that effective global actions require finding new ways to promote a more productive circulation of scientific data and exercising greater control over data fruition so as to prevent the unlawful dissemination of restricted information, while making more data available to users' communities.

While greater availability (and/or control) of (big) data may have a positive impact in addressing development challenges, it is somewhat problematic that data diplomacy literature treats data in terms of a "deficit model" (Wynne, 1991). It suggests that more data and datasets will "foster evidence-based decision making" (United Nations, 2015, p. 10) and that more data will stimulate rational choices without really considering social and global issues outside this data-driven perspective. This literature emphasizes "an enormous need for collection and analysis of data" without actually recognizing that is the elaboration of an analytical framework and the selection for specific data that allows for its interpretation that gives them value and that without such a framework data have no value at all if not *potentially* (Jacobson et al., 2018, p. 32).

Integration between data and "meta-data" offers instead a novel outlook on specific issues that datasets alone cannot address. The merits of this integration have been emphasized fairly recently especially in connection with the study of the genome, or the genetic material of an organism as defined by the DNA (Özdemir et al., 2014). Much of the current work within the field of genetics consists of putting together the data that relate to the code and in particular those that have to do with the sequences that are decisive in the synthesis of molecular structures (proteins, etc.). There are many institutes, worldwide, carrying out sequencing work that typically results in advances in genetics regularly reported in academic literature. While the genetic data provides critical information on the synthesis of life constituents such as proteins, there is equally critical information clustered in meta-data that tells us a great deal more about the mechanisms of expression in the creation of organic structures. *Genomics*, the discipline that focuses on meta-genetic data, is now considered as important as genetics when exploring growth and variation in living organisms. In addition, genomic-type analyses have become more important even outside biology, as proven by the proliferation of "–omic" study areas (or "omics" revolution), which emphasize the merits of integrating data and meta-data in the study of complex phenomena. A new journal, *OMICS*, has even promoted the understanding of how such integration can stimulate a fruitful dialog across disciplines.

Its wider appeal is partly associated with the recognition amongst scholars that social and global problems with a science and technology component cannot be addressed exclusively from a disciplinary-oriented data-driven perspective and need greater understanding and appreciation for the social and human conditions associated with the scientific and technical solutions envisaged for these problems. This is firstly because ignorance of specific circumstances (environments, habits, values, local knowledge) for foreseeing solutions often leads to controversial or even plainly erroneous solutions. In the 1980s an assessment about the radioactivity of soils in the Lake District (UK) carried out by Ministry of Agriculture experts failed to recognize what was instead fully known to local farmers thus erroneously attributing above average levels of radioactivity to the Chernobyl disaster rather than to the impact of the much nearer nuclear station of Sellafield (Wynne, 1998).

The crucial importance of the ready availability of a great diversity of data has emerged with particular gravity in the scientific uncertainties underlying the different national responses to the recent spread of the new coronavirus (SARS-CoV-2) initially hitting the Chinese city of Wuhan. The rapidity with which the COVID-19 epidemics has triggered a medical, economic and social crisis worldwide encouraged the adoption of new scientific practices for making immediately available, in an open access fashion, research products and data (Apuzzo and Kirkpatrick, 2020; Fox, 2020; Zastrow, 2020). Scientists are thus trying to work with a high production of diverse data to answer unsolved issues related to the COVID-19 pandemics, which include finding the causes of the high variability in mortality rates across different countries or regions (e.g., Bayer and Kuhn, 2020), evaluating the effectiveness of non-pharmaceutical interventions to decelerate the spread of the disease (Flaxman et al., 2020; Lai et al., 2020), as well as their effects on social and economic well-being.[4] It also entails investigating the role of environmental factors and social norms in the effective reproduction number of the disease (Qiu et al., 2020; Xu et al., 2020). At the same time, the current crisis shows the many issues in terms of science diplomacy of a too restricted view of what are considered the relevant scientific data in relation to epidemic modeling's assumptions in informing national and international sanitary policies (Fuller, 2020; Ioannidis, 2020).

Likewise, climate change issues are aptly (but somewhat simplistically) synthesized in terms of efforts to reduce CO_2 locally and globally and put in place mitigation measures, and this synthesis often entails a problematic sponsorship for geoengineering solutions; something that has raised controversy especially on the occasion of the publication of the 4th IPCC Report. The report was criticized as "legitimizing" geoengineering rather than helping to produce an integrative understanding of what solutions could be viable (Stilgoe, 2013). It is notable that the rapporteurs rejected several requests for reviewing the final draft grounded on works presenting substantial historical evidence about the problems associated with geoengineering. In particular, the work of Jim Fleming (2010) on the subject, emphasizing the hubristic nature of geoengineering interventions, was not integrated in the final report making space only for hazier point that geoengineering solutions might make things worse or result in inequalities (IPCC, 2014, pp. 36–38 and 41). In the end the historical datasets were mothballed and not integrated with the climatological data.

The merits of genomics and the shortcomings of non-integrated examinations of climate change issues suggest introducing a virtuous model for convincingly integrating in a structured way data and meta-data. Moreover, it supports the view that independent analyses by different cohorts of scientists specializing in different fields should integrate to produce truly trans-disciplinary analyses combining data about the natural world and human society as a way to address global societal challenges. This strategy allows taking the best from both these analyses also providing decision-makers with a range of options in implementing responsible innovation locally and globally. In what follows, we provide details of a specific approach that could successfully cater for this integration.

Data vs. meta-data interactions: a Linked-data multi-layered approach?

We propose here that recent advances in two areas of scholarship, network theory and computing, create both the formal basis for the feasibility of an approach and a theoretical framework that allows connecting and interpreting a variety of data of different kinds thus catering for data/meta-data integration. This framework is based on two methods. The first one is the Linked-Data method that has been developed in connection with the evolution of Web technologies (Berners-Lee, 2009). The second one is the multi-layer approach in network theory, which allows for an analysis of different kinds of entities (*nodes* in network jargon) and of the relations between them (*links*) within one and the same formal framework, both conceptual and mathematical (Bianconi, 2018). Altogether, these approaches allow overcoming the data/meta-data divide and direct us towards an analysis of interlinked data.

The Linked-data framework is based on the continuously increasing availability of interlinked data in the Web, which dismantle the hierarchical structure upon which rests the data/meta-data divide. Within the Linked-Data approach, data are built using technological frameworks so that they can be read by machines through semantic queries—a structure that has been called the Semantic Web (European Semantic Web Symposium, 2004). At least in principle, through these queries researchers can retrieve a set of interlinked data from different sources. A globally standardized framework to build structured datasets based on the Linked-data method poses the formal basis to connect a diverse range of data all linked between them. In this way, the definition of what is data and what meta-data depends on the specific enquires of the analysts, allowing for a multitude of flexible approaches to the issues of interest. In other words, the division of scientific data (data) and contextual data (meta-data) of a different nature (cultural, social, political, economic) can be flexibly set by the analysts once all different kinds of data are structured in a formal (interlinked) way. A proposal for standardized data taking based on the Linked-data framework has, e.g., recently been proposed in the emerging field of computational history of science (Damerow and Wintergrün, 2019; Wintergrün, 2019). In addition, internationally standardized tools for meta-data description of bibliographical and cultural items—such as the CIDOC Conceptual Reference Model (Doerr, 2003)—are increasingly shifting toward the adoption of the Linked-Data canon (Schilling, 2012). We see in this movement toward the standardization of meta-data modeling with the Linked-data framework a possible strategy for the elaboration of the more complex analysis of data/meta-data interaction here proposed.

Taking into consideration a great variety of (big-)data modules is an enormous challenge, but there are advances in graph theory and complex systems analysis that are designed to cope with this challenge. The Linked-data framework is intrinsically related to network theoretical approaches, both at the conceptual and methodological levels (Wintergrün, 2019). The relevance of links in meta-data modeling naturally leads to interpret the specific data in relation to the set of data related to it. So that meaning is retrieved through the analysis of the structural position of specific elements within a net of relations with other entities. As we are proposing to put more emphasis than has been done so far on contextual data related to specific scientific data, one also needs a reliable model to quickly analyze this complex set of relations between different entities and draw some statistically reliable conclusions.

The multi-layer network theory allows for this analysis. Developed especially in the field of sociology to quantitatively analyze the interrelations between different kinds of social relations and their dynamical evolution (Dickison et al., 2016; Lazega and Snijders, 2016), the multi-layer approach has been, very recently, formalized as a specific branch of graph theory. This formalization has permitted a robust application of the multi-layer network theory to other fields, so that one has now a full set of mathematical rules that effectively allow to carry out what we are proposing to do in this essay: to analyze, at least in principle, how different elements have interacted with each other in the past and create dynamical network models that can inform policy-makers about the incidence of specific science and technological innovations in connection with the social, cultural, political, economic spheres in different local contexts.

The fact that multi-layer modeling of the interrelated dynamics of very different kinds of entities is, in principle, feasible has led to the emergence of the problem of how to model interactions between sub-systems of different nature, especially with the explicit goal to assess the global challenges of the Anthropocene in the framework of earth-system sciences (Subramanian, 2019). Donges et al. (2018), for instance, have put forward a taxonomy for modeling global environmental change based on three levels: the biophysical level, the socio-metabolic level, and the socio-cultural level. Crucial element of the taxonomy is the hypothesized set of interactions (links) connecting each layer to the others as well as of feedback loops one might expect from these interactions. This approach provides an example of advanced multi-layer modeling that takes into account disciplinary divisions in the definition itself of the analytical levels. In this way, a multi-disciplinary collaboration is explicitly embedded in the model itself, as the data come from different disciplinary domains.

Similar kinds of schematic taxonomies of multi-layer analyses have also been employed in the history of science to assess the relations between social actors (the social layer), material representations of knowledge (the semiotic layer), and more abstract knowledge elements (the semantic layer) in the dynamics of knowledge systems (Renn et al., 2016; for applications to historical cases see Valleriani et al., 2019; Lalli et al., 2020). This kind of approach necessarily implies the development of alternative working practices in the humanities based on close multi-disciplinary collaborative environments (Laubichler et al., 2019).

We have then the technological framework, the mathematical apparatus, and proposed taxonomies to analyze multiple inter-related datasets in order to identify those research projects that can effectively bring science diplomacy to assess more effectively global challenges. Indeed, exercises to evaluate research practices and methods have grown intensely with the goals to promote robustness in science against the mushrooming of novel disciplines, each with different standards and practices. The inspiration to build a robust "science of science" has been one of the motors behind Derek J. de Solla Price's intellectual activity, duly recognized by his public designation as the father of scientometrics (De Solla Price, 1963). However, in line with the "statactivist" approach, we argue for a critical evaluation of numbers, statistics and graph descriptions that while catering for integrative analyses, do not necessarily configure new numerical evidence as prompting *imperatives* in the social domain, but rather offer elements for further investigating solutions and debate the potential of different solutions within the wider society.

This is partly because we are familiar with how, in the last decades, quantitative evaluation of researchers' scientific outputs has problematically informed national academic and funding policies (see, e.g., Baccini et al., 2019). Moreover, we know that providing quantitative rules based on scientific outputs for individuating the emergence of scientific innovation and novel fields has been difficult. Various attempts at providing such rules (see, e.g., Bettencourt et al., 2006, 2008, 2009) had little impact in the science policy domain. The focus on data of scientific outputs is not sufficient to assess the role of research in the human society, and a more complex approach is needed. Moreover, to do that, an interdisciplinary approach based on relevant meta-data can be valuable (Ioannidis, 2018). We conclude that science diplomacy could be made more effective by promoting the integrative analyses sketched so far in this article. In essence a "science diplomacy 2.0" should have the ambition to propel responsible innovation across the world through a data-driven examination of research with potential to addresses social priorities and global demands. Who should provide this data-driven approach? In our view, this should be the task for purposefully designed "observatories" that science diplomacy initiatives should more emphatically promote.

Science diplomacy 2.0? Promoting the observatories

If science diplomacy, as many practitioners claim, can be a device to propel scientific collaborations across borders, then its ambition to tackle global challenges greatly depends on what kind of collaboration it promotes. We thus see a science diplomacy 2.0 to pay greater attention to societal and global challenges by providing instruments that allow policy-makers to better decide between competing collaborative research. One critical instrument informing this choice would be the responsible innovation observatory. Such an observatory would pool together data (and meta-data) from various disciplines and integrate them through the linked-data, multi-layered approach. The deriving results would be thus elaborated with the ambition of understanding what kind of research areas should receive priority in a world-region depending on local social demands, or even at a global level, depending on challenges to humankind and its environment.

The most cited example of an observatory of this kind is the WHO Global Observatory on Health R&D. Since 2013, the observatory has sought to identify health R&D priorities based on public health needs, by "consolidating, monitoring and analyzing relevant information on the health R&D needs of developing countries; building on existing data collection mechanisms; and supporting coordinated actions on health R&D" (WHO, 2014). The underlying justification for such an observatory is that the availability of contextual knowledge (or meta-data) about the incidence of epidemics and diseases can actually guide governments and sponsors in making decisions about future allocations of funding. It is important to stress that this is not an approach necessarily "warping" funding opportunities. If any, would allow anyone who is in a relevant funding position to make informed choices when selecting specific projects. Equally, researchers would not prevent from freely exploring what they wish, but this approach would entail the observatory to make funding recommendations for prioritizing some research areas that demonstrate social impact.

The WHO observatory is not the only relevant example of how one can promote responsible innovation through the accumulation of meta-data. Another recent example is the EU Horizon 2020 Research and Innovation Observatory (RIO). This is outlined as a policy support facility aiming to regularly report on national R&I systems and to produce cross-country analyses too. There are equally important examples at the national and local level of institutes seeking to make greater sense of research impacts. For instance, the Oslo Institute for Research on the Impact of Science (OSIRIS) in Norway seeks to develop meta-data-driven research analyses to improve research systems and inform science policy.

This is not to say that responsible innovation observatories exist only at the international level. Advanced nations such as France and Germany, for instance, been equipped with similar observatories, also through the use of European funds.[5] However, we suggest here to place their promotion at the center of international science diplomacy initiatives rather than within the context of national efforts, and, as the next paragraph shows, we also argue for the merit of connecting transnational observatories at local and global levels.

Science diplomacy could play a positive role in several, interconnected, ways to the growth of data-driven responsible innovation observatories. First, science diplomacy could openly embrace the global challenges agenda by sponsoring the adoption of these observatories in a number of countries across the world. It could also promote a more structured approach to international scientific collaboration that is not the result of individual initiatives (at times supported by government sponsors in light of unstated interests), but rather as a way to embrace a trans-disciplinary and integrative research culture. Those involved in science diplomacy schemes would thus work towards promoting the setting up and development of innovation observatories and their staffing with scholars and scientists of different disciplines eager to identify research priorities for one country or one world-region. In turn, they would also promote ways to advance further discussions between those elaborating this new knowledge and the local stakeholders to verify if the results of these trans-disciplinary and integrative research exercises match what they foresee as research priorities. Once this is ascertained, were-to-be "science diplomats" would work with their own governments and international organizations to pool the resources needed to take prioritized international collaborative projects to completion. We see these efforts as more targeted interventions resulting from an analysis of what are the societal priorities at local and global level. This work could display the importance of integrative, pluralistic scientific analyses that do not single out one specific set of data as decisive in defining R&D trajectories or even social interventions, but rather promote a truly engaging relationship between experts in a variety of fields.

We also foresee that the observatories could be of different types and responding to different challenges depending on their reach and thematic areas. Global responsible innovation observatories could be set up on specific themes of international/global reach to promote worldwide integrative analysis (on health, climate change, etc.) and inform with their integrated data analyses networks of regional observatories more concerned with data integration at local levels. Whatever their type and range of activities, such observatories will need to tackle a series of challenges in order to implement the proposed methodology to support the production of data. In particular, this production is still modest in the social sciences and the humanities in comparison to other sciences, so an imbalance in data integration will have to be addressed. Moreover, observatories will have to deal with the legal, ethical and political issues associated with data privacy and develop robust strategies for data protection. Finally, they will have to support the necessary training in educational settings, and promote some form of data acquisition standardization on top of meta-data integration.

As for the last point, rather than with some degree of automation through the use of machine learning techniques, we propose such an integration to be achieved through close international infrastructural coordination of the proposed observatories both at the local and global levels. In fact, it would be important that observatories do not re-produce monolithic models of data production through traditional academic indicators (bibliometrics, patent databases, clinical trials, etc.) or so as to replicate traditional expert vs. lay dynamic, but rather pursue approaches based on the "co-productionist" framework herewith outlined. Moreover, we would think of local, indigenous knowledge to be represented in the observatories at two important levels. First, in trying to find ways to integrate the results of different approaches to knowledge into the multi-layered network approach so as to emphasize aspects of local knowledge that are traditionally overlooked in expert-based analyses. Moreover, also to present the results of observatories' multi-layered analysis to local/regional stakeholders to as to get a much better sense if the research priorities of social and global impact envisaged through research match what is perceived within the local population. While local indigenous knowledge might not necessarily be always available, the co-productionist approach employed by the observatories will result in greater efforts to collect such data at the same time overcoming the ethical and political issues of the unregulated reuse of indigenous data (Radin, 2017).

Conclusion

What science diplomacy really was in the past is the subject of ongoing historical research yet to accomplish. How it is presently being advertised seems to contradict the preliminary results of this research, envisaging science diplomacy as a "win-win" option in international affairs benefitting scientists, decision-makers and stakeholders alike. We have shown in this paper that in the future science diplomacy will only realize the promise of being the transformative tool in international relations that its advocates want only if key policy provisions and directions are elaborated. In particular, we see the actual aligning of science diplomacy exercises and responsible innovation analysis as decisive to this transformation so that the practical benefits to local and global communities deriving from international scientific collaborations can be fully appreciated. We have offered in this article some general ideas about how future science diplomacy initiatives could more readily demonstrate their social impacts by recalling the centrality of data analysis and integration. Drawing on recent "omics", "linked-data" and "multi-layered" approaches we have thus emphasized that a "science diplomacy 2.0" should be construed as the promotion of integrative data analyses grounded on trans-disciplinary scientific work helping to envisage research priorities globally and locally. It should also be outlined as promoting the infrastructures needed, i.e., the innovation observatories, for these studies to be completed. It should finally be understood as facilitating the implementation of the schemes that are prioritized in this trans-disciplinary and integrative research. On the whole, the transformative qualities of science diplomacy will truly come to the fore when, rather than coming into support of one group of states or disciplines, they will promote the social and global transformations that the integration of hard and social sciences promises, and that original collaborative schemes outlined by the responsible innovation observatories would deliver.

Data availability

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Notes

1 On these H2020 projects see their websites: "Inventing a Shared Science Diplomacy for Europe" (InsSciDE, http://www.insscide.eu) and S4D4C "Using Science Diplomacy in/for Addressing Global Challenges" (https://www.s4d4c.eu/).
2 To explore these initiatives see the website of the Commission on Science, Technology and Diplomacy of the Division of History of Science and Technology (https://sciencediplomacyhistory.org/).
3 See the case study "Open Science Diplomacy" in the S4D4C project led by Katja Mayer and Ewert J. Aukes.https://www.s4d4c.eu/wp-content/uploads/2019/10/6-Open-Science-Diplomacy_A4.pdf.
4 See the state policy evaluation tool "The Health and Economic Impacts of COVID-19 Interventions" of the RAND Corporation https://www.rand.org/pubs/tools/TLA173-1/tool.html.
5 See for instance France's science and technology observatory (https://www.hceres.fr/en/science-and-technology-observatory-ost), and Germany's International Bureau (https://www.internationales-buero.de/en/index.php).

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Competing interests

The authors declare no competing interests.

Additional information

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