Foresight and responsible innovation: Openness and closure in anticipatory heuristics

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A B S T R A C T

The heuristic versatility of foresight is increasingly positioning this anticipatory instrument as a key resource to promote more responsible research and innovation practices. In a context where foresight's multiple heuristic potential is sometimes wrapped up in a promissory rhetoric that could lead to its being taken for granted, this article underlines the need to understand the emergence of these heuristics as being dependent on how foresight's dynamics unfold. By acknowledging the existence of more "open" or "closed" forms of foresight (which in turn can articulate more "open" or "closed" anticipations), the article argues that the degree of "openness/closure" of foresight activities is constituted during the *ex-ante*, *ex-dure* and *ex-post* processes, and according to the relations underlying their constructive dynamics. The main conclusion reached is that a pre-condition for foresight practices to become "instruments for" responsible innovation is to make them "subjects of" responsibility simultaneously. This involves monitoring the socio-epistemic relations whereby foresight practices are designed and executed, as well as monitoring how their emergent heuristics are translated into action.

1. Introduction

The main motivations and scope of normative frameworks and activities aimed at responsibilising innovation have varied over time (Ported, 1995; Schot & Rip, 1997). Nevertheless, since their inception they have sought to improve decision-making on the basis of representations of the futures that scientific and technological activities *may* (i.e. possible, probable or plausible futures) and/or *should* (i.e. desirable futures) "open up" (Coates, 1971; Rip, Misa, & Schot, 1995). Thus, activities aiming to promote more responsible governance of innovation practices have always been carried out in an anticipatory fashion (Poli, 2019a, 2019b).

However, the (meta-)theoretical and practical fragmentation of studies and activities that could be subsumed under the non-uncontroversial umbrella term "Futures Studies" (see Samet, 2010; Sardar, 2010) suggests that there are different approaches and dimensions to address "the future(s)", and different ways of translating them into action (e.g. Bell, 1997; Inayatullah, 1990). The diversity of theoretical and practical approaches currently coexisting in Futures Studies illustrates the heterogeneity of understandings and possible "uses" of "the future(s)", and thus the functional and heuristic diversity of anticipatory practices. The far-reaching conceptual distinction between "forecast" (i.e. empirical-predictivist) and "foresight" (i.e. non-predictivist) (e.g. Cuhls, 2003; Godet, 2012), and the many ways in which these two general approaches "to the future" are specifically conceived and applied in

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practice, might help to illustrate this diversity (Makridakis, Wheelwright, & Hyndman, 2008; Minkkinen, Auffermann, & Ahokas, 2019; Porter, 2010). Foresight is typically regarded as the main interventive and identitary terrain of Futures Studies (Son, 2015). It is, however, a polyvalent anticipatory tool defined by different objectives, functions and potential areas of operation. Foresight covers a broad spectrum of heterogeneous methods with different characteristics (in terms of rationales, goals, participants, etc.) and functionalities (compare Giaoutzi & Sapio, 2013a, 2013b; Karlsen & Karlsen, 2013; Minkkinen et al., 2019; Porter, 2010).

Foresight practices are commonly credited with being able to broaden the range of futures considered (Urueña, 2019) and enhance future literacies (Rhisiart, Miller, & Brooks, 2015). The anticipatory heuristics of foresight exercises have been increasingly recognised in contexts focused on promoting more responsible science, technology and innovation co-production practices (Barben, Fisher, Selin, & Guston, 2008; Brey, 2012; Grunwald, 2019; Stemerding, Betten, Rerimassie, Robaey, & Kupper, 2019; Swierstra, Stemerding, & Boenink, 2009; von Schomberg, Guimarães Pereira, & Funtowicz, 2006; Weber, Gudowsky, & Aichholzer, 2019). Indeed, over the last two decades, innovation systems (at least in the narratives) have increasingly moved towards more participatory and horizontal forms of governance and decision-making (e.g. Chilvers & Kearnes, 2020; Eizagirre, Rodríguez, & Ibarra, 2017; European Commission, 2001, 2002). Within this recent context, it has been claimed that foresight contributes to the better alignment of innovation with societal needs and ethical concerns (i.e. foresight contributes to more responsible innovation). Foresight's anticipatory heuristics are understood as an important entry point for improving critical awareness regarding the way the future is being shaped through science and technology in the present. This way of conceiving foresight in the context of innovation is not surprising; within Futures Studies, "[f] oresight is 'by default' devised to promote democratic processes through inclusiveness, openness, transparency, public engagement, and multi-stakeholder approaches" (Amanatidou, 2017, p. 1). By "creating transformative spaces for the creation of alternative futures" (Inayatullah, 1998, p. 815), foresight is commonly conceived as being able to empower and capacitate societal actors, integrate knowledge-systems, and/or even create "more whole human beings" (Ramos, 2006, p. 652).

This positive perception of foresight heuristics contrasts with some sceptical views that point to the possible shortcomings that may arise from exercises dealing with representations of the future. Nikolova (2014, p. 8), for instance, warns that (participatory) foresight exercises sometimes "deviate from the initial intentions" and may "create *an illusion* of empowering the public" (emphasis added). In the same vein, methods considered highly disruptive within the realm of science and technology governance such as sociotechnical or techno-moral scenarios (e.g. Arnaldi, 2018; Swierstra et al., 2009; Withycombe Keeler, Bernstein, & Selin, 2019) have been challenged by various critiques. In particular, critics, more or less legitimately, point out that the way futures are mobilised and framed in innovation practices are often permeated by biases (Bonaccorsi, Apreda, & Fantoni, 2020; Williams, 2006). For example, Nordmann (2014) notes that engaging with future representations may cause long-sightedness (i.e. detachment from the present), reify promises and visions, and/or reproduce misperceptions of control and determinism (see Boenink, 2013).

This article aims to problematise the arguable substantialisation (or "taken-for-grantedness") of anticipatory heuristics for steering more responsible innovation attributed to foresight exercises. In particular, the article underlines the need to understand the emergence of foresight heuristics as being highly dependent on how foresight's dynamics unfold. Foresight is functionally and heuristically variable in terms of the spectrum of potential alternative futures and capabilities that it might anticipatorily enable for (de)construction. Given that this degree of "openness/closure" of foresight depends on its constitutive dynamics, a pre-condition for these exercises to unleash their full potential as "instruments for" responsibilising innovation is to consider them "subjects of" responsibility. Considering foresight exercises as a "subject of" responsibility would entail monitoring the socio-epistemic relations whereby they are progressively co-constructed throughout the whole process (i.e. throughout the *ex-ante*, *ex-dure* and *ex-post* foresight operationalisation phases).

In order to develop this proposal, first it will be shown how foresight has been increasingly recognised as a valuable "instrument for" steering more responsible research and innovation. This value lies in its alleged potential to problematise (or "open up") the diverse anticipatory dynamics shaping innovation governance (Section 2). It will then be argued that anticipatory foresight heuristics and functionalities and their respective degree of "openness/closure" should not be taken for granted, but rather be understood as dependent on how the constructive relations between its constituents unfold (Section 3).[1] More precisely, it will be theoretically argued that foresight's constitutive socio-epistemic dynamics are influenced by a series of sociotechnical constraints (or "hampering factors"). These sociotechnical constraints modulate the "openness/closure" potential of foresight practices during their *ex-ante* (Section 3.1), *ex-dure* (Section 3.2) and *ex-post* (Section 3.3) operationalisation phases. The article concludes by emphasising the need to make foresight a "subject of" responsibility whilst simultaneously being used as an "instrument for" responsibilising innovation practices. This responsabilisation of foresight would entail critically examining and problematising, *in real time,* the constitutive socio-epistemic dynamics being (un)favoured and/or (dis)enabled (as well as their underlying rationales) (Section 4). This article therefore proposes that the focus be broadened from improving scientific-technical and innovative design and development processes through foresight to the design and development of foresight itself. Although foresight has the potential to make design and development processes more responsible, such potential depends on how foresight is designed and operationalised within the sociotechnical fabric in which it operates. Foresight thus needs to be "responsibilised" by monitoring (and caring for) its constructive dynamics.

The findings presented here may be of particular interest to foresight practitioners whose main area of operation is science, technology and innovation. For instance, it may be of interest to foresight practitioners engaging with normative frameworks such as Responsible Innovation, Responsible Research and Innovation, Anticipatory Governance, or Technology Assessment (among others). Some Futures Studies scholars and practitioners may also see this article as a modest, reflexive insight into the design, implementation, and assessment of their "worldmaking" practices (Vervoort, Bendor, Kelliher, Strik, & Helfgott, 2015).

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[1] In this sense, the article aligns with the constructivist epistemology that seems to articulate (more or less tacitly) Futures Studies nowadays (e.g. Bell, 1997; Fuller, 2017; Fuller & Loogma, 2009; Inayatullah, 1990).

2. Anticipations and the governance of sociotechnical systems: Foresight as an "instrument for" responsible innovation

The "use" of the future as a praxiological guide for the present (i.e. anticipation) is a pervasive phenomenon. It crosses and articulates the activity of diverse physical, biological and social systems (Nadin, 2016; Poli, 2017). Over the last three decades, the field of Science and Technology Studies has seen a growing interest in the narratives and discursive elements that permeate and constitute science, technology and innovation practices (Fuglsang, 2001; Hess & Sovacool, 2020). Part of this interest has led to the development of analytical enquiries that aim to highlight, illuminate and critique the performative role of representations of the future steering science, technology and innovation processes. Examples include recent developments in the Sociology of Expectations (Borup, Brown, Konrad, & van Lente, 2006; Brown & Michael, 2003; van Lente & Rip, 1998) or theoretical proposals concerning sociotechnical imaginaries (Ballo, 2015; Jasanoff & Kim, 2015; Jasanoff, 2020; McNeil, Arribas-Ayllon, Haran, Mackenzie, & Tutton, 2017).[2] What all these studies diagnose is that science, technology and innovation activities are not immune to anticipatory embodiments (Brown, Rappert, & Webster, 2000; Konrad & Böhle, 2019).[3] Indeed, "the future" is largely (if not entirely) rooted under different forms in the macro, meso and micro co-production and assessment of innovation practices (Konrad, van Lente, Groves, & Selin, 2017).

In the context of modern, highly industrialised and market-based societies, innovation has been radically associated with the impetus to generate and manage expectations and visions of high economic value (Beckert, 2016). Expectations, visions and imaginaries are currently understood as anticipatory means to justify and promote certain techno-industrial practices. Indeed, innovation practices are typically understood as eminently knowledge-based and future-oriented. Such practices are aimed at creating *new future action possibilities* with far-reaching socio-economic implications and meanings.

Innovation, however, besides being an element in the construction of realities—an element of "creative destruction" in Schumpeterian terms (Schumpeter, 1942)—, is itself co-constructed (Jasanoff, 2016). It is a co-construction that takes place in broader sociotechnical systems, i.e. systems dynamically and relationally constituted by "heterogeneous ensembles of people, artifacts, infrastructures, research, cultural categories, norms and laws, and natural resources" (Hess & Sovacool, 2020, p. 3). Innovation practices and their outcomes are thus highly and necessarily *dependent* upon varying sorts of resources, interests, inertias, and dominant practices and discourses. Innovation practices and their outcomes are not alien to the relational dynamics constituting the sociotechnical settings in which they take place.

This relational-dynamic ontology emphasises that "social" and "technical" realities are inextricably intertwined and mutually co-produced. The settings in which innovation and anticipation unfold are therefore understood as a *hybrid* sociotechnical fabric. This sociotechnical fabric is dynamically governed by complex dialectics of co-constitution that are not free of tensions and power imbalances. For instance, the dominant (capitalist) economic relations in sociotechnical settings are reflected in the narratives of institutions steering science, technology and innovation policies. These narratives frame innovation as a key driving force to boost social welfare and market competitiveness (e.g. European Commission, 2009, 2018; see Rodríguez, 2018). This connection between economic, social and technological progress becomes especially notable in the narratives on "strategic" emergent technologies, which are perceived as highly disruptive (e.g. nanotechnologies, biotechnologies and artificial intelligence).[4] These dominant relationships are typically anchored to a set of inflated expectations regarding the socio-economic value of certain techno-industrial innovations (Alvial-Palavicino & Konrad, 2019).

Futures representations and modes of cohabiting "the future" are constitutive elements of the sociotechnical assemblage in which innovation practices take place. Future *time* horizons constitutively permeate the diverse epistemic, social, cultural and ethical-political dynamics articulating the governance of innovation practices (Selin, 2006). Among the heterogeneous anticipatory phenomena constituting the governance of sociotechnical systems, the performativity of futures nurtured by expectations (e.g. hope, hype, fear), visions and sociotechnical imaginaries has attracted particular attention (Borup et al., 2006; Jasanoff & Kim, 2015; Simakova & Coenen, 2013; van der Helm, 2009). These heterogeneous, mutable and plural coexisting expectations, visions and imaginaries are co-created and disseminated in many different ways by diverse constellations of actors. These prospective elements convey representations of the future which, operating as "anticipatory devices", modulate a multiplicity of sociotechnical synergies and material assemblages. They disseminate meanings that colonise and shape the "prospective structures" (i.e. the emotional, cognitive and volitional schemata regarding the future) of the various societal actors and fulfil them "by agency" (van Lente & Rip, 1998).

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[2] Please note that this article does not aim to take a specific stance on these and other lines of research within Science and Technology Studies. Rather, it uses the insights from this field to highlight some of the reasons underlying foresight's increasing pervasiveness in normative frameworks of innovation governance.

[3] As Selin (2006) notes, discourses on emerging technologies are located in disparate or different temporal horizons. However, their "not-yet-existent" character often qualifies them as important niches for anchoring promises and speculations about the sociotechnical configurations they might enable.

[4] Specialised literature typically distinguishes between "incremental innovations" (i.e. aimed at improving existing products and processes) and "disruptive innovations" (i.e. aimed at generating dramatic changes in markets and industries) (e.g. Ettlie, Bridges, & O'Keefe, 1984; Nagy, Schuessler, & Dubinsky, 2016). However, according to the relational-dynamic ontology advocated in this article, this distinction is neither essentialist nor categorical. On the one hand, the distinction between "incremental/disruptive" innovations is not essentialist because "incrementality/disruptiveness" is not perceived an inherent feature of innovations per se, rather as a feature stipulated *in relation to* the characteristics of the sociotechnical setting of which innovations form part. On the other hand, this distinction is not categorical in that the incremental/disruptive nature of innovations is gradual and prone to variation. Moreover, the attribution of "disruptiveness" to an emerging technology is not anticipatorily unproblematic. For instance, attributing "disruptiveness" may respond to an attempt to associate such technology with promising futures. Characterising a technology as "disruptive" can serve as a rhetorical resource to legitimise and promote its current development practices (Berube, 2004).

Representations of the future that successfully articulate anticipatory actions help to coordinate the actors and efforts in order to achieve certain goals via certain means. They contribute to the legitimisation and organisation of science and technology (Rommetveit & Wynne, 2017), and help steer socio-political spaces of controversy (Michael, 2017) and contestation (Brown et al., 2000). Three examples of basic anticipations at work are: (i) The misleading idea of innovation-based linear progress still present in different policy narratives (Selkirk, Selin, & Felt, 2018), (ii) the distribution of funds on the basis of the promissory futures that an emergent technology might "open up" (Beckert, 2016, p. 184), or (iii) orbiting innovation policy agendas around the so-called "Grand Challenges" (Kuhlmann & Rip, 2018). Such anticipations illustrate how the alleged transformation of "prospective structures" engendered by representations of the future may refer not only to *content* (the specific expected, envisioned or imagined futures), but also to the *formal* commitments whereby the future itself is approached (e.g. as (i) a straight trajectory, as (ii) a vantage point and as (iii) a project, respectively).

Together with the aforementioned anticipatory dynamics articulated in visions, expectations and sociotechnical imaginaries that guide innovation practices in a more or less implicit manner, there are other anticipatory dynamics that *intentionally* and *explicitly* aim to promote more responsible innovation governance. Science and technology responsibilisation practices have increasingly articulated their activities in mainly *prospective* accounts. In contrast to *retrospective* accounts of responsibility (where responsibility is reactively *attributed* after the event), *prospective* accounts appraise responsibility proactively. Responsibility here is proactively *taken on* beforehand on the basis of more or less robust models of potential normative or exploratory futures. By including a forward-looking dimension, these responsibilisation activities have often embraced explicit anticipatory behaviours.

Explicit and intentional anticipatory practices are, however, heterogeneous (Poli, 2019b). Different modes of intentionally "engaging with" and "using" future(s) coexist, each one configuring different possible ways of articulating and operationalising future-oriented responsibility (Adam and Groves, 2007).

Among the different ways of approaching the future as a means to promote more responsible innovation, the most conventional is the empirical-predictivist. Empirical-predictivist approaches frame the future as a space that *can* (and perhaps *should*) be epistemically apprehended. This empirical-predictivist mode of anticipation is typically articulated in forecast exercises, which can indeed be highly effective at preventing, avoiding or mitigating some undesirable effects of innovation. This effectiveness especially manifests itself when the target is a system with high ontological stability, and where low degrees of uncertainty exist.[5]

However, this empirical-predictivist mode of conceiving and operationalising responsibility has some theoretical and practical shortcomings that could narrow the scope of innovation responsibilisation processes both intensively (i.e. in terms of how many effects and how comprehensively and systematically they are addressed) and extensively (i.e. in terms of the research and innovation stages to be implemented). For example, the causal complexity characterising certain emergent innovations (e.g. nanotechnologies), together with the ontological openness characterising the sociotechnical and techno-moral systems, constrain the intensive scope of this empirical-predictive anticipatory response (Hoffmann-Riem & Wynne, 2002). Moreover, predictive models for responsible innovation hinder the promotion of a contingent, non-linear view of the co-evolution of sociotechnical systems and narrows the set of outcomes considered problematic. Since anticipatory practices articulated in empirical-predictive future models often act as mere *external* correctives of innovation's potential *outcomes*, they are also limited in terms of their extensive scope: They are not a proactive instrument for increasing normative reflexivity and problematising the *purposes* and/or underlying values guiding innovation *processes*. Similar to the mobilisation of expectations, visions and imaginaries, forecast activities can be conceived as subtle reification mechanisms of existing knowledge co-production patterns and their guiding purposes. In short, forecast-based responsabilisation activities subtly reproduce inertias of uncritical "closure" (Feenberg, 1991). They do this by keeping certain outcomes, purposes and processes of innovation safe from socio-political problematisation.

The two anticipatory "closure" dynamics mentioned above, namely the *de facto* (where visions, expectations and imaginaries play a performative role and shape realities) and the interventive-predictive (where prospective responsibility is narrowly based on forecast exercises), have been widely recognised and contested. On the one hand, proposals such as Vision Assessment (Grin & Grunwald, 2000; Lösch, Heil, & Schneider, 2017) or "governance of and by expectations" (Konrad & Alvial Palavicino, 2017; Konrad & Böhle, 2019) seek to increase awareness and reflexivity regarding "closure" dynamics generated by expectations, visions and/or sociotechnical imaginaries. On the other hand, proposals such as Future-Oriented Technology Assessment (Nazarko, 2017), Real-Time Technology Assessment (Guston & Sarewitz, 2002), Technology Assessment (Sotoudeh & Gudowsky, 2018; Weber et al., 2019) or Anticipatory Ethics (Brey, 2012), seek to problematise and enrich the narrow, empirical-predictivist modes of future-oriented responsabilisation (e. g. by explicitly problematising the political and/or normative factors in the equation). Common to all the previous proposals (and others not mentioned here) is their emphasis on the need for foresight to "open up" the uncritical anticipatory "closure" inertias that

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[5] The fact that forecast exercises can be more or less effective depending on the context to which they are applied should not lead to the misconception that they can be shielded from critical scrutiny. Among the fundamental elements of forecast exercises that should always be critically considered is the materiality of the forecasting techniques used (e.g. epistemic opacity of some computational models), the socio-cognitive biases that they may (re)produce, or the dangers of narrowing down the considerations to be taken into account regarding the future (Godet, 2012; Meijer & Wessels, 2019; Sarewitz, Pielke, & Byerly, 2000).

permeate their respective fields of action.

The suggestion that foresight should be an "opening-up" resource is even more explicit and radical in normative governance frameworks such as Anticipatory Governance (AG) (Barben et al., 2008; Guston, 2014), Responsible Innovation (RI) (Owen et al., 2013; Stilgoe, Owen, & Macnaghten, 2013) or Responsible Research and Innovation (RRI) (European Commission, 2013; von Schomberg, 2013).[6] The radicality of these frameworks lies in their impetus to problematise all the domains involved in innovation processes *in unison* (i.e. to "open up" the outcomes, processes and purposes of innovation) from their early stages of development by including a wide range of societal concerns and actors.[7] Foresight operates in the context of AG, RI and RRI (alongside other principles and dimensions) as a tool to problematise the values, processes and possible outcomes shaping innovation dynamics in a participatory way. As Barben et al. (2008, p. 986) note, foresight "aims to enrich futures-in-the-making by encouraging and developing reflexivity in the system".

These latter normative frameworks aim to transcend the dominant institutional tendency to understand responsibility according to a top-down approach. Namely, as an exercise that consists of imposing prefixed regulatory norms and values on technological innovations whose social significance, moreover, is unproblematised (Felt et al., 2007; Owen et al., 2013). Under AG, RI and RRI, the regulatory norms and values are not substantivized, or predetermined. These proposals' radicality lies in considering responsibility as a function of meeting a set of "opening-up" *procedural* dimensions (according to a bottom-up approach) (Pellé, 2016). According to AG, responsibility entails the "ensemble" of foresight, engagement and sociotechnical integration (Barben et al., 2008; Guston, 2014). RI claims that responsible practices are the result of conjugating anticipation, reflexivity, inclusion, responsiveness (Stilgoe et al., 2013) and openness (Owen & Pansera, 2019). According to RRI, all societal actors should "work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of European society" (European Commission, 2013, p. 4). AG, RI and RRI thus reflect a commitment to a "politicised" concept of responsibility, where responsibility depends on how the plurality of interests, factors and actors mobilised around the purposes, processes and outcomes of innovation are embraced and articulated (Eizagirre et al., 2017; Nielsen, 2016). What interests and actors are excluded from research and innovation processes? Whose motivations and what power relations are dominant? What are the socio-economic implications of privilege-based and unequal research and innovation dynamics? These and other similar questions lie at the heart of these more radical responsibility frameworks (Stirling, 2008).

When informed by these frameworks, foresight turns into an anticipatory heuristic resource for politicisation. This requires "the introduction of broader foresight" (von Schomberg, 2013, p. 51). A kind of foresight aimed at problematising and negotiating the visions, expectations, security scenarios, and political preferences involved in innovation dynamics. Problematisation and negotiation that, in turn, aspire to co-produce more socio-epistemically robust alternative futures (e.g. Owen et al., 2013, p. 38). Here foresight is conceived as an instrument to stimulate collective scrutiny of: (i) The (im)plausibility and/or (un)desirability of the futures shaping innovation practices in the present, and; (ii) how the future itself is approached. In other words, here foresight becomes an instrument for "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p. 1570). The future, in this context, is not primarily approached as a space to be epistemically conquered (Foley, Guston, & Sarewitz, 2018), but "as a negotiable political resource and discourse area that can be written on" (Bauer, 2018, p. 38). Foresight thus is conceived as a disruptive instrument which broadens the range of actors and concerns involved in innovation practices. It is an instrument to facilitate the imagining of alternative sociotechnical futures capable of transcending dominant, "business-as-usual", technocratic and economistic realities (Wiek, Foley, Guston, & Bernstein, 2016).

In conclusion, foresight is currently conceived and/or used by diverse normative proposals and frameworks as a comprehensive instrument aimed at enacting anticipatory heuristics. It is claimed that these heuristics "open up" the "closure" inertias that *de facto* constrain innovation futures-making practices. This "opening-up" occurs in multiple domains (outcomes, processes, purposes and/or expectations/visions/imaginaries), and according to different radicalisation gradients. Table 1 exemplifies (without claiming to be comprehensive, and according to "ideal-typical"[8] domains of application) some of these functions and heuristics for enhancing more responsible innovation ascribed to foresight practices.

Instead of taking foresight's positive heuristics for granted, the next section highlights the need to appraise them as the result of foresight practices' actual dynamics. In this sense, rather than approaching foresight exclusively as an anticipatory instrument to

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[6] Including foresight in these frameworks, however systematic, takes on a varying degree of explicitness. This inclusion is clearly evident in the cases of AG and RI in their respective "foresight" and "anticipation" dimensions. In the case of RRI, the inclusion of foresight is reflected in the recognition that RRI's operationalisation "implies, among others, the introduction of broader foresight" (von Schomberg, 2013, p. 51). Indeed, within the RRI framework, foresight is considered an instrument that enables "inclusive and integrated assessments of future science and technology" (European Commission, 2017, p. 9).

[7] The degree of radicality, or "openness", of normative proposals is therefore defined in this article in terms of: (i) The areas of innovation covered (What domains of innovation are problematised?); (ii) the time variable (When is the innovation problematised?) and; (iii) the degree of inclusiveness (Who sits at the negotiation and governance table?). For example, a normative framework that limits responsibility to impacts may be considered less "radical" than one that broadens its focus to include innovation processes and purposes. Similarly, an *ex-post* evaluation may be considered less "radical" than one conducted at its early stages of development (the latter allows innovation development to be modulated from the outset so as to avoid "technological lock-in" and sociotechnical entrenchment). Finally, a normative framework that is able to involve a wider variety of actors and concerns can be considered more "radical" than one where governance is confined to a small group of actors (e.g. experts).

[8] The innovation domains listed in Table 1 are "ideal-typical" in the sense that they do not reflect the inter-domain relationships in all their complexity and interactivity. The relationships between outcomes, processes and purposes are, in practice, rather characteristically messy, unruly and iteratively co-constituted. The apparent linearity responds exclusively to analytical-expository purposes.

Table 1

Examples of anticipatory heuristics and functions ascribed to foresight practices for responsible innovation.

Innovation domains	Examples of expected functions and heuristics
Performativity of expectations, visions, imaginaries	Social refinement / deconstruction of existing visions, expectations, imaginaries and/or development of new, meaningful ones (Grin & Grunwald, 2000; Konrad & Alvial Palavicino, 2017)
	Diversification and management of visions and expectations (Warnke & Heimeriks, 2008, p. 79)
Outcomes	Configure more "socially-robust risk research": Questioning fixed normative, empirical and technical-methodological assumptions and reframing how the assessment of the possible effects (e.g. risks) are being constructed (e.g. what variables are being overlooked; how are they interrelated and framed; what alternatives exist) (Stilgoe et al., 2013, p. 1570)
	Imagining sociotechnical and techno-moral co-evolution interplay between technology, society, morality and social practices, as well as exploring the plausible "hard/soft impacts" (Arnaldi, 2018; Boenink, 2013; Swierstra et al., 2009)
Processes	Function as a process moderator (Warnke & Heimeriks, 2008, pp. 81–82):
	- A tool for wiring up the innovation systems (Martin & Johnston, 1999) by establishing networks between actors (Barben et al., 2008)
	- Engaging other ways of knowing and co-producing knowledge (Selkirk et al., 2018, p. 6)
	- Creating inclusive spaces for mutual learning (Könnölä, Brummer, & Salo, 2007)
	- Building reflexivity into the design and development of emerging technologies (Selin, 2011, p. 175)
	- Promoting flexibility in response to ongoing developments (Boenink, 2013, p. 149)
Purposes	Allowing "shared explorations of desirable futures, thereby collecting tacit knowledge as well as social needs and values" (Gudowsky & Peissl, 2016, p. 8)
	Elucidating public preferences for various alternatives (Selin, 2011, p. 723)
	Identifying novel strategic opportunities (Arnaldi, 2018; Fuller, 2018)
	Enhancing "reflexivity, perspective-taking, and responsible decision-making" (Selkirk et al., 2018, p. 1)
Transversal anticipatory capabilities	Emphasising contingency, and "to better confront the linear model of time so as to recognize the complexities and systematic character of contemporary innovation" (Selkirk et al., 2018, p. 7), "including in particular the possibility of discontinuity and radical change" (Boenink, 2013, p. 152)
	Training in *phronesis*, or practical wisdom, by exercising imagination, perception, and even empathy (Boenink, 2013, p. 155)
	Building resilient societies (Barben et al., 2008; Fuller, 2018)

promote responsibility, this article claims that foresight itself needs to be monitored and be cared for. Thus, this proposal seeks to broaden the analysis of foresight practices. In contrast to more mainstream approaches, which are mostly interested in improving design and development processes through foresight and anticipation, the aim here is to highlight the need to monitor foresight's constitutive processes as well (i.e. foresight's design, implementation and evaluation processes).

3. Foresight as a "subject of" responsibility: towards monitoring futures-making dynamics

The previous section shows how foresight exercises have been positioned by various innovation governance frameworks or proposals as interventive instruments to "open up" anticipatory "closure" inertias (see Table 1). In this context, foresight practices are recognised as worldmaking mechanisms (Vervoort et al., 2015) serving as "instruments for" responsible innovation. Understanding foresight as an "opening-up" resource is, nonetheless, subject to variation. The *expected* degree of foresight radicality, in terms of its "opening-up" potential, varies in accordance with the normative framework or proposal from which it is framed and intends to serve. The various semantics surrounding "responsibility" affect and are reflected in the different meanings and expectations of "foresight" heuristics (and vice versa).

This variation in the meaning and expectations attributed to foresight's "opening-up" role is one of the factors influencing its heuristic potential, but not the only one. Foresight's heuristic potential is dynamically and relationally constituted throughout the course of the foresight design and operationalisation processes. Indeed, as Fuller and Loogma (2009) note, foresight is not only a mechanism for constructing realities, but is itself a construction. Foresight is both an "instrument for" responsible innovation and an innovation in itself. In short, it is an interventive tool made "in-the-making" that is spatially and temporally constituted. All of this implies that the valuable anticipatory heuristics of foresight practices do not arise *ex-nihilo*, but are in turn the contingent and situated outcome of the sociotechnical and socio-epistemic relations taking place throughout their design and operationalisation (Dufva & Ahlqvist, 2015a, 2015b). That is, the emphasis lies here in that both the type of heuristic and its respective degree of "openness/closure" do not arise by default. Instead, they are progressively constituted through the series of dynamics whereby foresight practices are operationalised and constrained. This means that foresight's degree of "openness/closure" stems from the dynamics occurring throughout its *ex-ante*, *ex-dure* and *ex-post* operationalisation phases.

The degree of "openness/closure" of anticipatory practices might be understood in terms of the amplitude of space for alternative "plausible" and/or "desirable" futures. This amplitude is enabled during the (de)construction of futures in light of the heterogeneous technical, methodological, axiological, volitional, socio-material, epistemic and/or affective constraints explicitly or implicitly established and/or co-negotiated during the whole process (Urueña, 2019). This means that reifying or substantivising conceptions where foresight's meaning and performativity are taken for granted should be avoided. Instead of assuming certain virtues of foresight practices, the socio-epistemic processes whereby such practices are performed and constituted need to be addressed. In addition to using foresight practices as "instruments for" responsible innovation, they must be simultaneously appraised as "subjects of" responsibility. This would require real-time monitoring of the conditions constituting foresight heuristics. It is important to elucidate the

"enabling/constraining" influence exerted on the unfolding of foresight practices by the sociotechnical networks in which they are put into practice.

This proposal is made in a context where foresight is perceived and presented by certain normative frameworks as an instrument for "opening-up" innovation processes. The degree of "openness" (or "disruption") attributed to foresight in AG, RI and RRI normative frameworks is particularly noteworthy. These frameworks, as outlined in the previous section, understand responsibility as a function of meeting a set of "opening-up" and procedural criteria aimed "at amplifying the still, small voices less often heard in the innovation process" (Guston, 2014, p. 229). In this context, foresight is conceived as an instrument to promote radically inclusive innovation processes.[9]

In the context of this tendency to conceive responsibility in inclusivist, or "political", terms (Eizagirre et al., 2017; Nielsen, 2016; Pellé, 2016), the aim here is to note that any foresight operationalisation must deal with sociotechnical inertial factors that seriously hamper achievement of the inclusivist ideal. Dealing with these inertial factors is crucial in order to (de)construct truly alternative and disruptive (i.e. not "business-as-usual") futures. This requires monitoring how "hampering factors" modulate the ongoing socio-epistemic dynamics of foresight, and thereby its heuristic "opening-up" potential. This is what is meant when the need to make foresight a "subject of" responsibility is underlined.[10]

To be more specific, some possible constraints or "hampering factors" to which particular attention could be devoted when foresight is made the "subject of" responsibility will be highlighted below. These "hampering factors" influence the main operationalisation stages (or "key points") of foresight in which its "openness/closure" potential is progressively determined. In the following sections, the key "opening/closure" points and "hampering factors" will be briefly presented. The presentation specifically relates to each *ex-ante* (3.1), *ex-dure* (3.2) and *ex-post* (3.3) phase of foresight operationalisation or development (summarised in Table 2).[11]

3.1. Ex-ante phase of foresight: Anticipatory "openness/closure" by design

The *ex-ante* phase encompasses both the practical design and recruitment of potential participants. The methodological steps for Design (also called "Scoping") and Recruitment are of great importance as they delimit the foresight framing, personnel and role selection, chosen methodology and/or level of inclusiveness in advance. In other words, they delimit an area of functional possibilities that the foresight exercise can deploy. As with the design of any other innovation, it constrains the affordances of the device in play (Faraj & Azad, 2012; Norman, 2013). By modulating, or guiding, the possible forms of knowledge co-production achievable in the exercise's subsequent phases, the design structures the potentially erectable socio-epistemic processes. It facilitates and/or hinders certain kinds of relations *ex-ante*, thus setting the *potential* "openness/closure" of their heuristics.

"Openness/closure" in this *ex-ante* phase depends on a series of key points regarding the methodological steps of both Design (i, ii, iii) and Recruitment (iv).

Concerning Design, three issues have been identified:

(i)   The innovation domain (i.e. expectations, outcomes, processes or purposes) where foresight is implemented.
(ii) The specific approach to the future. This issue concerns the constraints related to certain ways of representing, and cognitively and methodologically approaching, futures (e.g. predictive/empirical, cultural/interpretive and critical) (Inayatullah, 1990).
(iii) The level of techno-methodological accessibility for the actors. This entails monitoring how the methodology or technique in play enables some actors' participation whilst disenabling the inclusion of others.

As for Recruitment, consideration (at least) of the following issue is crucial:

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[9] The main motivation to focus this article on AG, RI and RRI is purely analytical (i.e. insofar as these frameworks primarily promote a disruptivist function of foresight, which is this article's main object of analysis). The article notes, however, that there are serious epistemic-political difficulties associated with the radical character of this type of approaches. It does not argue that it is epistemically or politically appropriate to eradicate all trace of functional specialisation from innovation-related decision-making processes. Moreover, these normative frameworks' procedural criteria are interpreted here as *flexible* principles of practice regulation. This means that AG, RI and RRI are themselves susceptible to variation in terms of both their conceptual formulations and practical instantiations; see Owen and Pansera (2019). Moreover, the article does not treat the openness ideal as inherently good. What is "more or less open" and how openness is evaluated are not questions that are raised *a priori*; rather, they are open-ended questions that are performatively resolved in the actual practices. All disruptive anticipatory dynamics are constitutively subject to resistances and tensions that *de facto* limit the degree of openness enabled by foresight.

[10] Understanding foresight both as a modulating and modelled element naturally follows the relational-dynamic ontology presented in Section 2. Ultimately, foresight's performance is the result of a dialectical process involving a heterogeneous set of factors. This dialectical process takes place within the sociotechnical fabric where foresight operates, and intends to modulate.

[11] Two methodological considerations related to Table 2 are worth noting here: (i) "Methodological steps" is an analytical reconstruction. Even though all the steps occur in foresight practices, the pattern does not have to be strictly linear in practice. Indeed, there may be iterative processes between methodological steps (e.g. following a (de)construction step, the need to include other actors and knowledge resources may be identified), as well as background overlaps (e.g. recruitment may be extended during the *ex-dure* phase). The apparent linearity responds solely to analytical-expository purposes. (ii) The "Key points of "openness/closure" and its associated hampering "closure" factors" do not aim to be comprehensive, and may be susceptible to future refinement and/or elaboration.

Table 2

Examples of "openness/closure" key points and associated hampering "closure" factors in the foresight *ex-ante*, *ex-dure* and *ex-post* development phases. Source: The "Methodological steps" and "Associated basic activities" have been adapted from Popper (2008).

Phase	Methodological steps	Associated basic activities	Key points of "openness/closure"	Hampering "closure" factors
Ex-ante	Design (or Scoping)	Foresight framing: Defining the rationale, purpose, target users, time horizon, etc.	Domain of implementation (expectations, outcomes, processes, purposes of innovation)	Preordained and/or uncontested constraints (e.g. pre-set purposes and processes; exclusive focus on outcomes; unproblematised expectations)
		Assembling the project team	Approach to the future that is enabled (and reproduced) through the method and technique in play	Methodological and technical performativities (e.g. futures-limiting material and formal constraints; time-frame dependency; limited resources)
		Designing the methodology (quantitative / qualitative / quantitative-qualitative)	Level of method and technique accessibility so as to include diverse societal actors	Funding biases (e.g. non-independence; lack of incentives for disruption)
	Recruitment	Selection / open call for actors and knowledge sources involved	Which actors and knowledge sources are included/left out and on what basis (i.e. degree of inclusion)	Socio-epistemic hierarchies (e.g. individual or disciplinary epistemic (in)justices; epistemic (in)competences) Exercise taming (e.g. number of participants; (de)complexisation of issues and messages) (Un)balanced resources (e.g. economic inequalities; informational partiality)
Ex-dure	(De)construction (or Generation)	Existing knowledge (codified, articulated, embedded…) is collectively amalgamated, analysed, and synthesised	Conducting the exercise: Topics (not) encouraged to be opened for discussion	Procedural performativity (e.g. moderators' abilities; closing-down of concerns; exercise structuring)
		Representations of the future are (de)constructed	Quality of the socio-epistemic relations (not) empowered (e.g. degree of reflectivity; responsiveness; inclusiveness)	Socio-epistemic hierarchies (e.g. individual or disciplinary epistemic (in)justices; epistemic (in)competences; argumentative (in)justices)

Table 2 (*continued*)

Phase	Methodological steps	Associated basic activities	Key points of "openness/closure"	Hampering "closure" factors
Ex-post		Other plausible/desirable futures are explored and/or analysed	Awareness of the overlooked plausible and/or desirable futures	Socio-cultural habits and ideologies (e.g. value-free science; reification of futures; trust in numbers; discipline-based tendencies; cognitive and normative biases)
	Action	Knowledge generated is translated into action	Degree of effectiveness when translating heuristics into action and maintaining this over time	Responsive rigidity (e.g. status quo and resistance to change; non-binding results; socio-material limitations)
				Funding bias (e.g. confirmatory biases; attention niches; problem reduction)
	Renewal	Monitoring and assessment of the possible steered transformations	Effects (not) monitored (why these and not (also) others?)	Sociotechnical limitations (e.g. (in)exhaustive monitoring of complexity; error intolerance; deficit in indicators)

(i) Deciding on the domain of potential participants. This involves considering, for example, how recruitment choices determine "participant" and "non-participant" domains.

These four key points ultimately predetermine the amplitude of alternative futures potentially producible during the *ex-dure* phase. Each of the foresight operationalisation key points mentioned above (whereby "openness/closure" is determined) are embodied in a set of sociotechnical dynamics whose inertias may arguably tend to "close-down" (Stirling, 2008) the constitutive relations (and thus the heuristic potential) of foresight practices.

On the one hand, concerning the methodological Design step, these dynamics are exemplified by hampering "closure" factors such as excessive focus on the outcomes of innovation dynamics (which may curtail, or disable, the potentially critical consideration of alternative processes and/or purposes). Moreover, factors influencing and constraining methodological and technical performativities may act as "hampering factors". For example, constraints imposed by existing material resources, the time-frame chosen or the specific cognitive process required by each individual technique modulate the scenarios considered and influence the ways "the futures" are approached. Last but not least, funding biases (such as the lack of incentives to produce disruptive futures and non-independence) may tend to align the exercise with those futures ideologically compatible with the principles and interest of the institutions and agencies in charge (Nielsen, 2014).

On the other hand, as for the Recruitment step, selection of the potential participant domain might be "closed-down" on the basis of a series of implicit or explicit factors such as individual or disciplinary epistemic injustices and/or (in)competences (Fricker, 2007). Furthermore, inclinations to make foresight exercises more manageable may result in a reduced number of invited participants. Combined with the fact that such exercises are vulnerable to different kinds of inequalities (ranging from economic to informational), a reduction in the number of participants could lead to the impoverishment (in terms of diversity and complexity) of the envisaged futures.

3.2. Ex-dure phase of foresight: "Opening-up/closing-down" futures generation

The exercises defining the *ex-ante* phase of foresight constrain the potential of the *ex-dure* (De)construction (also called "Generation") phase. Thus, having designed the foresight exercise and selected its participants, it continues to remain unfinished. Within the operating margins granted by the design and recruitment steps, there is room to develop more or less disruptive futures and thus, more or less "opening-up" heuristics.

The *ex-dure* phase refers to the methodological step of (De)construction, where the sharing and analysis of knowledge takes place among the various participants. The principal objective here is to (de)construct the futures and "open up" the range of possibilities to be considered at the time and/or enable a series of futures literacies. Among the key points that may modulate the "openness/closure" of foresight exercises in this phase are:

(i) How the (de)construction of futures is mediated or curated (e.g. the encouraged limitation of topics identified and addressed).
(ii) The kind and quality of the socio-epistemic dynamics constituting the (de)construction process.
(iii) Awareness of overlooked (im)plausible and/or (un)desirable futures.

Closure dynamics in this phase could be modulated by several "hampering factors". For instance, procedural styles and prevailing inertias may modulate the interactions produced and concerns considered, and could therefore shape the futures to be domesticated or presented and those to be dissipated or hidden. In this sense, foresight practitioners acknowledge that "stimulating debate always involves structuring and thus closing-down particular avenues of concern" (Selin, 2011, p. 734). Epistemic and argumentative (in) justices and/or (in)competences (Fricker, 2007; Linker, 2014) also play an important "hampering" role by limiting the set of normative-epistemic elements whereby futures are (de)constructed. In addition, the constraining influence of the ideological priorities and impositions underlying the (de)legitimisation of knowledge need to be examined (e.g. excessive trust in numbers, estimations of science as "value-free", and preconceptions of disciplinary hierarchies). Last but not least, personal or psychological biases must also be considered relevant foresight modulators (Bonaccorsi et al., 2020; Schirrmeister, Göhring, & Warnke, 2020; Tichy, 2004).

All these "hampering factors" (more or less explicitly) configure the relationships between actors when (de)constructing different futures (what and whose knowledge is considered). They condition both foresight's processes and its emergent products (what and whose futures are produced/highlighted and in relation to which dimensions). This modulation is of great relevance as only (de) constructed futures anticipatorily inspire action.

3.3. Ex-post phase of foresight: "Opening-up/closing-down" anticipatory enactments

Finally, the *ex-post* phase encompasses the methodological steps taken once "the heart of the process" (Popper, 2008, p. 48) (i.e. the *ex-dure* phase) has concluded. These steps include translating foresight heuristics into actions (the Action step) and monitoring and assessing the impacts of such actions (the Renewal step). Hence, it is at this point where foresight unfolds into "explicit anticipation" (Poli, 2017, pp. 266–268).

Similar to the previous two phases, this *ex-post* phase is also affected by key "openness/closure" points. Here, two key points are highlighted.

As for the methodological step relating to Action:

(i) Transferring heuristics into action can occur at different levels of intensity due to a variety of factors. These factors relate to the actors translating the action, and to the sociotechnical system in which the actors are embedded and operate (and aim to transform).

As for the Renewal step:

(i) The assessment criteria for the actual transformations (if any) might be prone to partiality in terms of the issues and considerations to be taken into account when monitoring such foresight impacts. In other words, the indicators used could reflect the interests and expectations pre-attached to foresight practices.

The main closure dynamics concerning the methodological step of Action is the (relative) lack of responsiveness from sociotechnical systems. This lack of responsiveness is the result of phenomena such as status quo resistances, socio-material limitations (e.g. economic and/or technical constraints) or non-binding exercises. The existence of deep-rooted sociotechnical dynamics (Belot & Picard, 2014) may limit the effectiveness of such practices in bringing about significant and persistent systemic changes (Nielsen, 2014).

One relevant "hampering factor" in the Renewal step is how funding biases incentivise the monitoring of a limited set of transformations. Namely, transformations falling within the universe of interests of those promoting the foresight exercise (thus overlooking other possible collateral transformations). Also, another relevant "hampering factor" affecting this step relates to how sociotechnical constraints encourage the emergence of certain deficits. These deficits concern, for example: (i) Thoroughness when faced with monitoring complexity; (ii) incentives to tolerate and reflectively accept and/or incorporate error, and/or; (iii) the availability and use of non-standard indicators (i.e. those capable of qualifying hard-to-measure-and-control phenomena).

In conclusion, the opening heuristics attributed *de facto* to foresight practices should be put into perspective. On the one hand, these heuristics are not predetermined, but rather the outcome of a series of socio-epistemically contextualised co-construction processes. On the other, "openness/closure" can occur in different gradients and in relation to different factors. There is always a closing and an opening element. This implies that an essential aspect of making foresight a "subject of" responsibility is to pay attention to (and care for) the socio-epistemic dynamics whereby foresight practices are conducted and constrained. Responsibilising foresight exercises requires that their *ex-ante*, *ex-dure,* and *ex-post* operationalisation phases be monitored.

4. Conclusions

The future is a fundamental resource for research and innovation practices. It modulates current scientific and technological processes by constraining the procedures and goals conditioning research and innovation paths. Representations of the future, whether in the form of expectations, visions or sociotechnical imaginaries, or through interventive-intentional foresight exercises, shape the anticipatory dynamics guiding future-making practices.

Foresight has been increasingly valued as an anticipatory interventive-intentional resource with great heuristic potential to promote more "responsible" research and innovation. "Responsibility" here can take different forms, or "degrees of radicalisation", depending on (i) the innovation domains to which it applies (outcomes, processes, purposes and/or expectations/visions/perceptions) and the extent to which these domains are influenced and problematised; (ii) when (or how early) the domains are problematised, and; (iii) the variety of actors and concerns involved.

In this respect, normative frameworks such as AG, RI and RRI exemplify a high degree of radicalisation. Within these frameworks, foresight is conceived as a dimension which, in conjunction with others, steers towards the problematisation of all the domains (*in unison*) involved in innovation practices from their early stages of development. This comprehensive problematisation of innovation needs to be conducted via the inclusion of a broad range of societal concerns and actors. In the context of these normative frameworks (AG, RI and RRI), foresight operates (alongside other principles and dimensions) as an inclusive anticipatory technique that aims to "open up" the values, processes and possible outcomes whereby innovation dynamics can be shaped, contested and negotiated. Foresight is considered an interventive tool designed to trigger a heterogeneous set of reflexive-anticipatory heuristics of great value in terms of facilitating more democratic science, technology and innovation. Such heuristics are heterogeneous. It is claimed that they enable the "opening-up" of alternative futures considered "(im)plausible" and "(un)desirable", and reinforce the actors' futures literacies (see Table 1).

This research article has confronted the arguable tendency to substantialise the anticipatory heuristics of foresight exercises so as to promote more responsible innovation (whether under more "radical" frameworks such as AG, RI and RRI, or under any other framework). It has been claimed that foresight's anticipatory heuristics are the result of situated socio-epistemic dynamics. This implies that the spectrum of potential alternative futures and enacted capabilities depends on how foresight's socio-epistemic dynamics unfold. This unfolding is not alien to the prevailing dynamics of the broad sociotechnical system in which foresight operates, and intends to modulate. In other words, the anticipatory heuristics' degree of "openness/closure" is progressively built up throughout the entire foresight process, i.e. throughout the *ex-ante*, *ex-dure* and *ex-post* operationalisation phases. Even the performance of foresight practices under regimes of "radically" inclusive frameworks of responsible innovation such as AG, RI and RRI is not foreign to these "openness/closure" dynamics.

It has been argued that foresight heuristics' degree of "openness/closure" is progressively resolved throughout the course of the foresight processes themselves. Therefore, focus should *not only* be placed on how foresight practices could improve the design and

development of technologies and innovations. Attention should *also* (and simultaneously) be paid to how foresight is designed and how its anticipatory development is progressively constituted. It demands attention to the crucial stages, or "key points", of foresight operationalisation processes where the "openness/closure" potential of foresight's anticipatory heuristics is modulated. Some "key points" are: The chosen approach to the future, actors included/excluded and ways of conducting the exercise, or how/to what extent the heuristics are translated into action.

This has led to the identification and analysis of certain "hampering factors" such as design-based constraints, methodological oversimplification of the exercise, socio-epistemic and argumentative biases and injustices or lack of responsiveness. "Hampering factors" can modulate foresight heuristics in the direction of "closure". Identifying them then becomes a highly significant task in order to expose the subtle sociotechnical constraints whereby certain potentially conceivable futures are discarded. Illuminating the existing "hampering factors" may serve to explain what and whose futures resist being envisioned and anticipated (i.e. imagined and translated into action).

This article therefore suggests that a pre-condition for foresight exercises to unleash their anticipatory "opening-up" potential (i.e. their potential as "instruments for" responsible innovation) is to consider them in turn "subjects of" responsibility. This would entail identifying and monitoring, *in real time*, the potential "hampering factors" modulating the sociotechnical relations whereby foresight exercises are progressively constructed. In other words, if foresight is intended to be used as a tool for fostering more responsible innovation, it must simultaneously be borne in mind that foresight is itself an innovative practice subject to the sociotechnical dynamics it seeks to influence, and on which it depends. As an innovative practice oriented towards the transformation of reality, the modes and processes constituting foresight must therefore be monitored and cared for (and that is what is meant by stating that foresight must be "subject of" responsibility).

Thorough analysis of such dynamics and their rationales in the terms stated above can help improve the understanding and heuristics of foresight practices (what/whose knowledge and futures are considered, and why these and not others) so as to "open up" the realm of potentially alternative conceivable futures. In other words, elucidating the set of "hampering factors" shaping and constraining the sociotechnical futures that are "(im)plausible" and "(un)desirable" could enhance the capability to critically and reflexively address how futures that impose certain dominant modes of conducting research and innovation are constituted and operate. This capability is a necessary (albeit non-sufficient) condition to propose and implement anticipatory science and technology governance dynamics that are more receptive to the inclusion of voices and concerns traditionally excluded when shaping sociotechnical futures and presents.

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Declaration of Competing Interest

The authors do not declare any conflict of interest

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