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# **Method Matters in the Social Study of Technology:** Investigating the Biographies of Artifacts and Practices

*Sampsa Hyysalo*

*Aalto University, Finland/sampsa.hyysalo@aalto.fi*

*Neil Pollock*

*University of Edinburgh, UK*

*Robin Williams*

*University of Edinburgh, UK*

## Abstract

Science and Technology Studies understandings of technological change are at odds with its own dominant research designs and methodological guidelines. A key insight from social shaping of technology research, for instance, has been that new technologies are formed in multiple, particular (albeit interlinked) settings, by many different groups of actors over long periods of time. Nonetheless, common research designs have not kept pace with these conceptual advances, continuing instead to resort to either intensive localised ethnographic engagements or broad stroke historical studies, unable to address both the intricacy and extent of the process in tandem. There has consequently been increasing interest in extending current methodological and analytical approaches through longitudinal and multi-site research templates. We discuss this fundamentally methodological critique and its implications through one of these approaches: the 'biographies of artifacts and practices' (BOAP) framework, which by now offers a twenty years body of studies to reflect upon methodological choices in different sociomaterial settings. This paper outlines the basic principles of BOAP and its significant variations, and discusses its contribution to STS understandings of innovation, especially user roles in innovation. We finish by arguing that if STS is to continue to provide insight around innovation this will require a reconceptualisation of research design, to move from simple 'snap shot' studies to the linking together of a string of studies.

**Keywords**: method, methodology, research design, sociotechnical change, social studies of technology, design, use

## Introduction

*Does STS have method?* There are perhaps few studies or episodes that throw into sharp contrast why STS scholars need to give more attention to its methods than Steve Woolgar's (1991) "configuring the user" paper. Back in the 1990s, Woolgar made the argument that technology design(ers) constrain the actions of technology users: user behaviour is configured by the designer and disciplined by the technology. Woolgar (1991: 59) wrote that through "defining the identity of future users and setting constraints upon their likely future actions", the technology (and the designer) constructs 'the user'. This concept was widely taken up. Along with a number of similar ethnographic 'laboratory studies', it became something of a model for how STS research on technology could or should be conducted. This template showed, most immediately the richness of knowledge from ethnographic studies of designer and user engagements with technology. A large number of similar studies followed, involving often intensive ethnographies of particular settings (e.g. Akrich, 1995; Oudshoorn et al., 2004). Mackay et al. (2000), in contrast, showed differently to Woolgar that configuration is not a one-way process: whilst designers do construct users, they are in turn configured by both users and the internal exigencies within their own organisation.

There are a number of potential things to say about this contrasting finding, most notably that, Mackay et al. (2000), in studying not just (one small part of) the design phase of the technology but also the technology's implementation and use, threw light on the limitations of the Woolgarian framework. They showed how Woolgar's research design, restricted to the study of actions and comments made by designers about the imagined 'user', produced a highly limited (and we may add, overly-politicised) account of design-user relations. This points to 'closure effects' that research design choices can have and their significant implications for the kinds of observation and interpretations the analyst might make.

The issue of how current analytical templates and research practices produce somewhat unbalanced and reductive accounts is a little-discussed feature within STS (Hine, 2007). It has been argued that, because of this, the discipline suffers from a problematic intellectual legacy that limits its potential application to wider domains (Golinski, 1998). In rallying against the universalistic claims of science and technology, STS has turned to and sought to generate a research programme out of methodological situationism (Knorr-Cetina, 1981; see also Burawoy, 1998). Importantly, as part of this, it has historically prioritised ethnographic engagements with science and technology in the making – often through intensive laboratory studies of science (Sismondo, 2004).

Unfortunately, a considerable part of the contemporary sociotechnical landscape is inconveniently structured for these forms of social scientific inquiry. Some of the key insights of early studies of the Social Shaping of Technology (SST) in the 1980s and 1990s (MacKenzie and Wajcman, 1999) posed a methodological conundrum for STS scholars embarking upon fieldwork. They showed how new technologies were hardly ever shaped in a single setting and that processes of sociotechnical change rarely occurred over the space of a few months (the typical length of a laboratory ethnography). Rather they emerge out of and across wide-ranging spatial contexts and are more often played out over many years (and, in some cases, decades).

To provide an adequate picture of technology shaping, as Hine (2007) has remarked, one would need to study not just the intricate practices of one particular setting but the wide range of locales in which a technology evolves and even perhaps the interlinkages across these settings. In the 2000s, a new wave, characterized as 'Mark II' SST research, argued for methodologies and frameworks that engaged with "a wider conception of relevant actors and of the terrain of transformation" (Russell and Williams, 2002: 71). This call was prompted by scholars seeking to reflect the role of users and various intermediaries groups in shaping technology (Sørensen, 1996). This meant the array of settings necessary to understand the dynamics of technological change was multiplied even more dramatically. Others have gone further still, arguing the need to study both actors and structures (e.g. Bijker, 1995), stability and change (Bijker, 1995; Geels et al., 2016), etc. In part this recognition has emerged in response to theoretical debates around the neglect of structural conditions in both ANT and SCOT, resulting in overly situational and potentially internalist analyses (Klein and Kleinman, 2002; Russell, 1986; Woodhouse, 1991).

Here an inconvenience arises, however, because in calling for (more) sophisticated understanding of technological change, STS scholars promote modes or (perhaps more precisely) 'visions' of research that go beyond or are at odds with their currently accepted analytical templates and research practices. Indeed, many of those advocating more encompassing approaches (e.g. Bijker, 1995; Geels et al., 2016) have themselves not lived up to the standards they espouse. For instance, those calling for the inclusion of broad historical overviews of technology development, alongside more intricate detail of technology-in-the-making (Bijker, 1995; Geels et al., 2016), have tended to assume that the phenomena that come into view with close up, real time, inquiry do not differ from the view offered by broad historical sociology. Overall, these considerations points to the need to begin to discuss the import of *research design and methodological matters* in S&TS in addition to theoretical debates, and in doing so recognizing that the research design issues are not hard-wired to particular theoretical traditions. At the same time, most discussions about methodological choices have remained deeply undertheorized and led to generic prescriptions in methods handbooks, and in so doing lost sensitivity to sociomaterial contexts investigated.

The dangers of inadequate or limited research designs are not trivial. As Law (2007) has convincingly shown, methods are performative. The same goes for research designs and study templates: the investigator's choice to limit or conversely extend the scope and scale of the research design will yield a significantly different picture of the agency, structure, impact and materialities related to the technology under investigation as illustrated by our discussion of the diverging understandings of design emerging from Woolgar's (1991) and Mackay et al. (2000) different research framings. Scholars have begun to address these issues, questioning current analytical templates and seeking to remedy them through setting out alternative perspectives sensitive to the extended (both in space and time) nature of contemporary technological development, for instances through 'infrastructure' (Bowker and Star, 1999), 'knowledge infrastructure' (Edwards, 2010) or 'information infrastructure' (Monteiro et al., 2013). Critiques of existing research designs and proposals for alternative have also emerged around the 'biographies of artifacts and practices' (BOAP) framework, which has evolved from its first articulation in the 1990s to a point where today there exist close to twenty long-term studies of information systems, health care technologies, social media, energy technologies to name a few. The approach has developed into a coherent alternative in thinking about methodological and research design choices. In this paper we take stock of its development and import for research designs in S&TS, underscoring for instance that the portrayal of users in innovation changes further once extended research templates are used to investigate it.

We first outline the basic rationale and principles of BOAP, and discuss some of the common variations in how it has been pursued. In particular, we show how BOAP throws light on a blind spot in the otherwise emphatically reflexive STS field (Lynch, 2000): This is the failure to give consideration to such issues of how research results may be as much affected by the study framing as by theoretical point of departure. This is startling given STS attempts to explain the practical everyday accomplishment of science and technology in the making. It points to a weakness in the discipline. After this, we review how BOAP studies, in various ways, call into question some taken for granted assumptions concerning innovation. We focus in particular on conceptions of the role of the user and user-led innovation. We finish by noting one consequence of the BOAP approach: that, if we wish to develop an effective understanding of contemporary technological innovation, we will need new kinds of research design - a move from 'snap shot' studies to the linking together of 'a string of investigations'.

## Biographies of artefacts and practices: origins, rationale and key facets

### *Origins and rationale of biographies of artifacts and practices research*

The BOAP approach had two key sites of emergence in the mid- to late- 1990s, one in Edinburgh and the other in Helsinki, which merged into a shared research program by the mid-2000s. Both strands drew from SST research and its original emphasis on "technology in the making". Though

**Table 1:** Studies on Enterprize Systems

| **Studies to capture the biography of Enterprize Systems in multiple interlinked settings** |
|---|
| Industry applications software leading to Commercial Off-The-Shelf solutions (Brady et al., 1992) |
| Computer-Aided Production Management (CAPM) leading to Enterprize Resource Planning (ERP) systems (Williams, 1997a) |
| Extension of ERP to higher education and its implementation (Pollock, 2000; Cornford and Pollock, 2003; Pollock & Williams, 2007) |
| Producer – User collaboration in developing new ERP modules (Pollock et al., 2003) |
| Evolution of Product Data Management technology in China (Wang, 2007) |
| Generification strategies by producers to extend ERP to new contexts (Pollock et al., 2007; Pollock and Williams, 2008) |
| Development and customer support by vendors (Grimm, 2008, 2012; Pollock and Williams, 2008; Pollock et al. 2009) |
| Package Software User groups and their influence on vendors (Mozaffar et al., 2015; Mozaffar, 2016; Pollock and Hyysalo, 2014) |
| Industry Analysts role in the Packaged Software Marketplace (Pollock and Williams, 2008, 2016) |

initially often focused on laboratories and production facilities as the key places to study technological change (Bijker et al., 1987; Law and Bijker, 1992; MacKenzie and Wajcman, 1999), by the 2000s STS research had evolved to recognise the roles which consumers and users played within artefact development (Silverstone et al., 1992; Sørensen, 1996; Oudshoorn and Pinch, 2003). This threw light on the cycles of 'domestication' and 'appropriation' as adopters adapted systems to meet local circumstances, and the wide range of actors, particularly intermediate and final users crucial in getting new systems to work (Fleck, 1988, 1994; Miettinen and Hasu, 2002; Pozzebon and Van Heck, 2006; Sørensen and Williams, 2002; Williams and Edge, 1996). Since these cycles could be played out across multiple locales and extended timeframes, scholars sought improved research templates that could capture the range of intertwining settings involved in the evolution of complex technologies, effectively moving the studies beyond 'innovation journey' that had typically be assumed to end with successful commercialization (van de Ven et al., 1999; van de Ven and Poole, 2005) .

The idea of that artifacts would have 'biographies' that feature different states of existence in connection to the social relations wherein they become to feature was proposed by Kopytoff (1986). Extended beyond only commodification process as Kopytoff used it, the 'biography of Artifacts' seemed a fitting metaphor to characterize the extended and evolving nature of innovation that takes place at multiple sites and times in which, for instance, software applications in manufacturing and the service sector became shaped (Brady et al., 1992; Pollock et al., 2003; Pollock and Williams, 2008).

Parallel in timing to these Edinburgh studies, Finnish researchers used Activity Theory to investigate how Health technology innovations were shaped in networks of 'activity systems' and, in turn, how the involved organisations and practices evolved in the process (Miettinen, 1993; Hasu, 2000; Miettinen and Hasu, 2002). Examining change not only in technologies but also in practices, organizations and institutions was adopted in the cohering approach 'and practices' added to it (Hyysalo, 2010; Pollock and Hyysalo, 2014).

To date BOAP research has engaged with several types of technologies. The longest research lineages has been on Enterprize Systems (See Table 1) and health technology innovations (see Table 2) that were used to develop the BOAP methodology. Once the approach had become more elaborated in late 2000s it was more programmatically utilized, adapted and extended in a range of other settings and studies (Table 3).

**Table 2:** Biographical Studies of Health Technologies

| **Studies on Health Technology development, use and evolution** |
|---|
| Development and use of Magneto-Electroencephalo-Graphy (MEG)-brain imaging technology (e.g. Hasu, 2000, 2001, 2005; Hasu and Engeström, 2000; Miettinen and Hasu, 2002) |
| Collaboration in Positron-Emission Tomography (PET)-tracer development (Hyysalo, 2000), |
| Collaborative design and use of Diabetes management databases (Hyysalo and Lehenkari, 2002, 2003), |
| Design and use of Safety alarm technology for the elderly and disabled (e.g. Hyysalo, 2003, 2004, 2006a, 2006b). |
| Development of Telechemistry diagnostic analysers (Höyssä and Hyysalo, 2009), |
| Living lab development of safety floor system for elderly care (Hakkarainen, 2017; Hakkarainen and Hyysalo, 2013, 2016; Hyysalo and Hakkarainen, 2014) |
| Evolution of electronic prescribing systems (Mozaffar et al., 2014; 2015; 2016) |

**Table 3:** Biographical Studies on other settings since 2005

| **Introduction of new formation systems in Greek Banking (Kaniadakis, 2006)** |
|---|
| Social Media: Virtual world for teenagers (e.g. Johnson, 2013; Johnson et al., 2010) |
| Evolution of new wireless telecoms standard Wibro (Suh, 2014) |
| User innovation and peer support in Small scale renewable energy technologies in Finland (e.g. Freeman, 2015; Heiskanen et al., 2014; Hyysalo et al., 2013a, 2013b, 2016a, 2017, 2018; Juntunen, 2014) |
| Arctic all terrain vehicles (Hyysalo and Usenyuk, 2015; Usenyuk et al., 2016) |
| Social media: Platform for teachers and learners (Hannukainen et al., 2017) |
| Digital disruption in recording industry (Sun, 2016) |
| Development of strategic planning software for Automotive manufacturing (Wiegel, 2016) |
| Maritime interdiction in the war on drugs in Columbia: practices, technologies and technological innovation (a.k.a. narco-subs) (Guerrero, 2016), |

### *BOAP key principles and concepts*

The above BOAP studies highlight eight recurring characteristics, which can be considered core markers of the approach. Rather than seeing these as a 'definition' of BOAP, they should be seen as minimal inclusion criteria. They represent different methodological responses to the marked contingencies in sociotechnical change, which make it difficult for researchers to reliably predict in advance (for instance on the basis of theory) what might be revealed and occluded by selecting a singular or limited set of vantage points . We insist that BOAP is a methodological (and in that capacity in part meta-theoretical) approach to the study of sociotechnical change that is compatible with several substantive traditions in the STS field as we point out in discussing each marker:

1. BOAP studies must have sufficient spatial and temporal *reach* to empirically engage the dynamics of the studied phenomenon (e.g. studies could look at an individual innovation together with the evolution of an industrial field). The studies must encompass the multiple loci and times wherein sociotechnical change is shaped and move beyond singular 'snap-shot' accounts (e.g. those accounts that portray phenomena from a singular vantage point of e.g. designers Woolgar, 1991 or consumers e.g. Silverstone et al., 1992). This is in line with the call by Marcus (1995) for *multi-sited ethnography*, going beyond particular organisational settings being particularly relevant to highly dispersed processes of scientific and technological life (Hine, 2007; Monteiro et al., 2013) and by those advocating more structural considerations as part of S&TS analyses (e.g. Klein and Kleinman, 2002; Russel, 1986);

2. The shaping of technology and practices must be viewed as taking place within *ecologies of interconnected actors,* and not only study the actors only with respect to how affect the studied technology (e.g. see Bijker's [1995] "relevant social groups") as this leaves aside the rationales by which they operate. It also misses the often complex and subtle mechanisms by which actors within an ecology interrelate (Russell, 1986; Hyysalo, 2010; Pollock and Williams, 2016). This BOAP premise is similarly found in other ideas and disciplines (e.g. 'linked ecologies' (Abbott, 2005); 'social worlds-arenas' framework (Clarke and Star, 2003); 'networks of activity systems' (Engeström, 2000));
3. It may be particularly fruitful to identify and research *interstices,* the moments and sites in which the various focal actors in the ecology interlink and affect each other and the evolving technology. An overall understanding of the ecology of actors is typically used to pinpoint key locales where these interstices may be researched in detail, perhaps by ethnographic means. A typical case is Hyysalo's (2004) delineation of 'visible handshakes': settings and processes by which developers and users of health technology were effectively co-constructed. Similarly Mozaffar's (Mozaffar et al., 2015, Mozaffar, 2016) study of the innovative role of packaged software user groups, led her to quickly realise that the key developments were no longer in the subgroups she had chosen to study, leading her to shift field sites until she had traced how the innovation activities had evolved (Mozaffar, 2016). The focus on interstices is shared by many in S&TS, classic cases being Hennion (1989) and Callon et al. (2002) yet the use of broader scale analysis to identify the sites to focus on is more rare, yet found in studies of infrastructures Monteiro et al., (2013); Ribes and Polk, (2015) and in studies examining the evolution of scientific fields (e.g. Cambrosio and Keating, 1995; Edwards, 2010; Fujimura, 1996);
4. Pursue research at multiple temporal and spatial *scales*. BOAP is at odds with accounts that assume sociotechnical change could be adequately understood through a 'birds-eye' descriptions only. There is a need to bridge between the analyst's bird's eye view and the actors' real-time 'frogs' eye' perceptions, which typically feature high levels of uncertainty and contingencies (e.g. the 'fog of innovation' (Höyssä and Hyysalo, 2009)) that can entirely disappear from historical data and broad overviews. 'Data grain size framing effects' e.g. where studies limit themselves to just one preferred level of data and analysis (a.k.a 'granularity bias' (Hyysalo, 2010)) are surfaced in BOAP investigations time and again. Questioning the dominant research framings in literature can be the starting point for inquiry into a richer set of contexts (e.g. Stewart and Hyysalo, 2008) or the major outcome of the investigation (e.g. Hyysalo, 2010; Pollock and Williams, 2008, 2016). This facet is shared in STS oriented technology and organisation studies in studies of practices (e.g. Nicolini, 2012), Activity theory (Cole, 1996; Engeström, 2000) and in Symbolic Interactionist Social worlds – Arenas framework (Strauss, 1978; Clarke and Star, 2003; Clarke, 2005);
5. Different temporalities and spans of change are seen as *multiple enacted contexts* (Hyysalo, 2004, 2010), not as the ontologically distinct layers that emerge for example from the 'multi-level perspective' (Braudel, 1995; Geels, 2002; Geels and Schot, 2007) or the traditional approaches that locate action within context conceived as 'surrounding layers' (Strauss and Corbin, 1990). In BOAP, events are seen as simultaneously constituting and being constituted by broader patterns: the context for any situation is understood as being comprised of differently paced constituents, as previously discussed in microhistory (e.g. Levi, 1988) and socio-cultural psychology (Cole, 1996; Engeström, 1987) and in distributed cognition (e.g. through the 'Hutchins cube' where the same moment is analysed in terms of the development of practitioners, practices and the situated enactment of action (Hutchins, 1995)). BOAP thus seeks to inquire into the links between relevant constituents to see their influences and interrelations (or lack of). Studying different contextual constituents

means employing an array of often differing, conceptual tools, analysis types and methods to diverse materials (Hyysalo, 2010: 43). BOAP's preference for ethnographic study thus does not mean an in-built 'micro sociological' focus, but an examination of how the structuring elements are present in real-life situations, and in turn, how the situations reshape the structuring elements and what can be learned about the patterns and structures as they are enacted. The position resonates with Situational analysis by Clarke (2005) yet refrains from flattening the empirically salient topologies in contextual factors (Star, 1995) and thus differs markedly from actor-network theory (Latour, 1987, 2005) or Ethnomethodology (e.g. Suchman, 1987);

6. Investigate the shaping and shape of technology in the process. Akin to many STS approaches, BOAP studies insist on paying attention to *materiality*: the content and form of technology as it shapes, and is shaped by, the interrelations between actors (Latour, 2005; Kallinikos, 2004). This goes for the material nature of the focal technology studied (and differences that results from these being e.g. complex large software systems, discreet physical objects, or only partially tangible methods or services), as well as the production systems, tools and infrastructures which designers and users enact in their practices (cf. Cambrosio and Keating, 1995; Galison, 1997). This is to say, BOAP insists on carefully investigating the different materialities and their effects in different sites and times of technology's life and carefully reflecting on what this entails for the overall research design - something more often claimed than carefully done in social studies of technology!;
7. Create *balanced and empirically adequate* accounts of the different actors in the ecology phenomena, rather than assume, for instance, that key design decisions would be made by designers (for, as we discuss below they often come from users);
8. Attend to the *detailed dynamics of sociotechnical change* both empirically and theoretically. This has been the focal interest in all BOAP research to date. It has involved pursuing a detailed understanding of change in different settings and moments. This is at odds with resorting to high-level depictions of sociotechnical change. We discuss below the risk that widely adopted SST conceptions of sociotechnical change *as* 'social construction' or *as* 'mutual shaping' or 'systems transition' as a template to characterise the relevant processes and nett outcomes may be used as an excuse for high level generalisation that occludes the detailed processes constituting it (see below section on main findings of BOAP program) (Bijker, 1995; Schot and Geels, 2007; Geels et al., 2016).

To further clarify this rationale let us contrast the BOAP approach to the methodological criteria for investigating the socio-technical change in classical STS studies. For instance, Bijker (1995) notes that a theory of sociotechnical change needs to provide symmetrical explanation of success and failure; to engage with change/continuity; and the interplay between actor/structure in the seamless web of technology production. While we agree with these points, our dissatisfaction with large bodies of STS studies is that they struggle to live up to their own criteria due to their unduly simplistic and limited research designs. In this respect, the above BOAP core elements offer a set of *guideposts* for what it would mean if scholars sought to take these ambitious goals seriously, in light of our current understandings of sociotechnical change.

## BOAP research designs and what these imply for S&TS researchers

Ideally, as the above guideposts suggest, BOAP investigation would connect in-depth studies of the various interlinked actors involved in, and affected by, the sociotechnical change in question. This means deploying a number of mutually complementary studies on different aspects of the biography of technology, and over different time frames of analysis. Practically, the development of BOAP investigations may be more or less programmatic depending upon the availability of resources (e.g. staff time, the research funding environment) and access constraints. The beginnings of a BOAP investigation may not differ much from any other STS research, but as the research progresses, previous research is extended to a string of further studies – building upon existing knowledge and the various ideas/issues that unfold from this work, reflecting upon puzzles and gaps in understanding and emerging theorising.

Herein lies an important research design issue that is not unique to BOAP but concerns STS research broadly: what does one do after initial research set-up and findings? STS authors critiquing situated single site analyses share this concern (Karasti and Blomberg, 2018; Hine, 2007) and BOAP studies have been fiercely critical of STS researchers' apparent infatuation with single 'snap-shot' studies that are often rich on detail and insight, but by necessity limited to a single locus and moment and often revolving around the perspective of a single actor group– offering a narrow viewpoint in the process of how technologies are shaped (Hyysalo, 2010; Pollock and Williams, 2008). Reflecting on our own evolving research practices we observe that BOAP research design progressions feature different kinds of *continuation strategies*:

1) There is an opportunity to extend enquiry longitudinally – which may serve to increase our robustness of understanding of innovation processes and their outcomes and in particular to revisit knowledge claims made in previous studies (which as Pollock and Williams (2008) note, in their ERP study, were almost the reverse of the eventual outcomes) and in this way explore the effects of temporal closure on findings. Extension has taken place either through follow-on studies in affinity to ethnographic studies of infrastructuring (e.g. Karasti and Blomberg, 2018) or through an historical analysis of the studied phenomena and its context (e.g. Hyysalo, 2004; Hyysalo and Usenyuk, 2015; Pollock and Williams, 2008; Usenyuk et al., 2016) in affinity to activity theoretical studies (Engeström, 2000; Miettinen, 1998).
2) There is an opportunity to broaden the empirical scope of study across different settings. Here there may be a balance between what we may describe as intensification and excursion:
   a) *intensification* – characterises studies which have pursued a more comprehensive and detailed exploration of the developer-user nexus (e.g. Hyysalo, 2010; Hyysalo and Usenyuk, 2015; Johnson, 2013), where research has progressed through several parallel scales of inquiry: from tracing the biography of a technology development or the evolution of practices in use to undertaking episodic studies (of varying durations of minutes to months) of design, appropriation/implementation and use. As these parallel studies progressed, focal points for detailed ethnographic enquiry would begin to be selected: chosen so that they are likely to be informative with regard to broader scales of change in design–use relationships as indicated by previous studies and/or likely to reveal patterns in sociotechnical change that were of special interest for the study.
   b) *excursion* – refers to cases in which the follow-on studies engage with new sets of relationships, locales, and types of actors identified in previous studies. In the course of such a journey, the research questions are likely to change significantly. Thus the research journey undertaken by Pollock and Williams took them from addressing ERP implementation challenges (Williams, 1997b), to understanding the developer–user nexus in packaged software development (Pollock and Williams, 2008), to understanding the knowledge infrastructures and new kinds of actors which underpin the operation of the IT market (Pollock and Williams, 2016). Similarly, Hyysalo et al. (2013a, 2016a) have moved from user innovation in renewables to peer support, to user created information infrastructures, to user roles in affecting energy transition (Heiskanen et al., 2014; Hyysalo et al., 2013b, 2018).

## *BOAP investigation data, methods and interpretation*

STS research is often given credit for its versatile data gathering and analysis methods. The variety in available data tends to grow with multi-sited and longitudinal studies such as those in BOAP, which have typically combined ethnographic and historiographic methods including the collection of documents, in-depth interviews and records of field observations. Access and data availability regularly feature as key research design consideration in BOAP studies. Given the increasing salience of electronic communication (especially in studies of social media and software packages), digital traces of user behaviour and design change logs have proven very useful (Johnson, 2013). Pollock (Pollock and Hyysalo, 2014) gained unrestricted access to a key informant's email communications across a long timeframe, which allowed for tracking the interplay between actors in detail as it evolved. The studies of user innovation in renewable home heating analysed half a million posts on Internet discussion fora in varying detail (Hyysalo et al., 2013a, 2013b, 2016a).

Multiple data sources and types allow both data and method triangulation (Denzin, 1989). Extending S&TS enquiry beyond single settings emphasises how different data types and sites of data collection also typically have their own framing effects. Ethnographic observation, recorded in field notes and audio and video recordings provided a first-hand experience of the realities of design and use of technology. However, these are 'noisy' and chaotic settings; understanding and experience accumulates only slowly and partially – some elements may be taken for granted; other processes may not yet be readily recognised by involved actors or research scholars but may only emerge over time or by contrasting different settings. Interviews provide a more focused method of eliciting knowledge but may be shaped by the interests and self-justification of actors involved. Thus interviews with technology developers may be coloured by their (often enthusiastic) visions and goals and may therefore conflate potential with achievement. Users, whose perspectives are constrained by particular locales, conversely may be well versed in current practices but may lack the breadth of experience or skills needed to develop a clear picture of unfolding developments or anticipate futures. The immediacy of ethnographic insights arising from field observation and interview could bring to the surface particular conflicts, concerns and events that appeared particularly interesting for research, and in this way assist in analysing other sources of data, such as documents, but could conversely tempt scholars to exaggerate the unique importance of the particular processes, events and settings observed.

Similarly to other multisite studies, BOAP research designs are built to allow for the further juxtaposition of different actors' narratives and perspectives, and in doing so increasing the trustworthiness and robustness of analysts' interpretations through two mechanisms. First, through studying different actors across several interlinked sites and comparing juxtaposed accounts, otherwise taken for granted features and local *framing effects* can be unpicked and balanced accounts of interaction created. Moreover, second, the extended scope of study tends to level out particular actor concerns or displays put on for the ethnographer when one enters the site over a sustained period.

A characteristic feature of data analysis in BOAP studies has been a recursive movement between different data-sets and different sampling strategies to examine data at different grain-sizes. Analysts typically seek to construct some overarching narrative(s) of the biographies in question (whether this is over months, years or decades). At the same time, they typically work on more detailed analyses of the most interesting processes within and perspectives on the data. Often the two proceed in parallel: when the analyst develops insights into specific events, s/he typically explores possibilities to trace connections and smaller or larger contributions to the overarching narrative(s). The broader scale descriptions, in turn, help to position particular events in relevant contexts. Figure 1 offers a stylised representation of the research design developed for Hyysalo's (2010) study of safety-alarm systems for the elderly. The arrows represent research activities; circles represent shorter episodes that the informants or the researchers regarded as particularly significant. Different bodies and granularities of data and time frames of analysis were systematically compared.

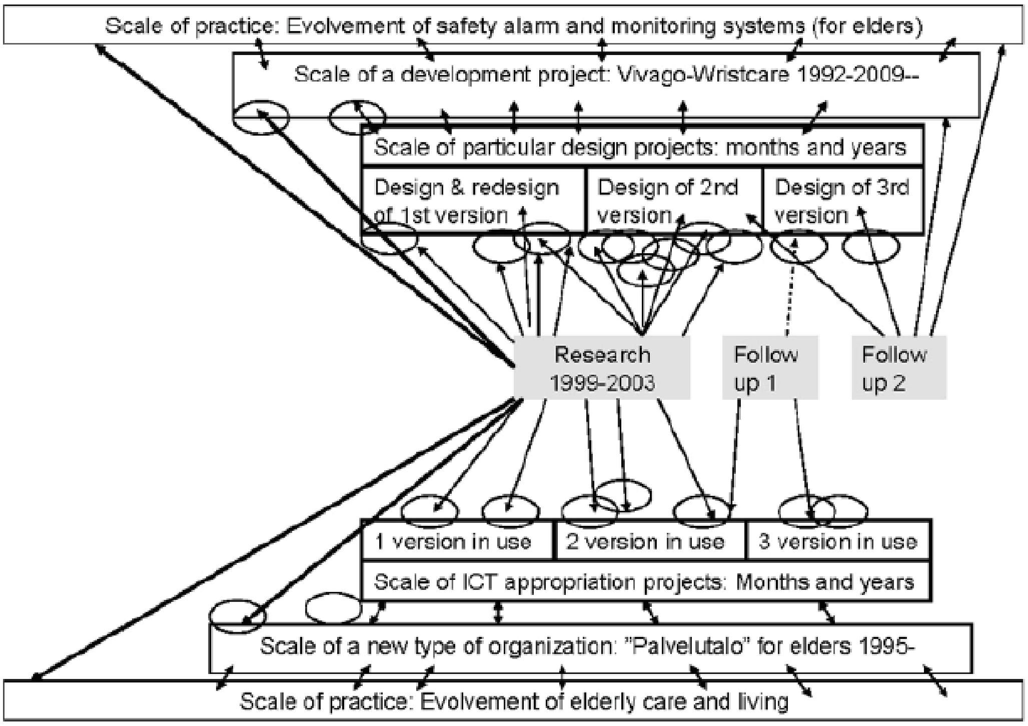


**Figure 1:** BOAP Research design on studying health technology in a start up.

We now illustrate why this research approach and analysis procedures are worthy of attention on the grounds of its contribution to theory building by examining four instances where BOAP studies have called into question widely established understandings of innovation, and in so doing, opened up a series of new questions and resonances between STS and related approaches in innovation studies and design research.

## BOAP as a vehicle for empirical and theoretical knowledge creation: Some key findings

### *Beyond User involvement as localisation and empowerment*

In STS and related fields oriented to responsible design (e.g. participatory design, human centred design, computer supported collaborative work), user involvement has traditionally be seen as a vehicle for empowerment, and a means for achieving effective technologies (Hyysalo et al., 2016a; Schuler and Namioka, 1993; Simonsen and Robertson, 2013; Stewart and Williams, 2005; Voss et al., 2009a). As well as ensuring user participation and engagement in implementing new technologies, this has included calls to involve users, including end-users who will operate the technology, in systems design and development. This view of the importance of involving users – with their knowledge of existing technologies and operating procedures - finds a close parallel with studies of the role of users in Innovation Studies. Here scholars have differentiated user domain knowledge and manufacturing domain knowledge and highlighted the presence of difficult to transfer 'sticky' knowledge between these domains (Baldwin and Von Hippel, 2011; Tyre and Von Hippel, 1997; Von Hippel, 1988, 2005).

Findings that have emerged from longitudinally following technology development in multiple sites within BOAP studies call into question some of these 'one-sided' accounts of users and innovation. For example, its equation with empowerment, or the assumption that user involvement early in the systems design is the most decisive way to bring user domain knowledge into design (contrasted by instead the ways in which users contribute to the reworking and evolution of technology in use - see below). BOAP also foregrounds how user involvement is not necessarily only about localisation (another key presumption). Users are also involved in efforts to 'generify' packaged products, in detaching their features from those matching too closely particular localities and become suited in a variety of different customer sites (Hyysalo and Lehenkari, 2002, 2003; Pollock et al., 2007; Pollock and Williams, 2008). Generification can potentially disgruntle existing users as their specific needs may end up deprioritised in the redesigns that render the package appealing to wider clientele (Hanseth and Bygstad, 2015; Johannessen and Ellingsen, 2009). To mitigate this risk, producers have been found to pursue various user involvement strategies. First, users (as individuals, as particular organisations or as broader user communities) are part and parcel of what may be strategic development directions for the vendor. They are also monitored for user developed solutions that can be incorporated and further iterated into producer offerings (Johnson et al., 2014a; Mozaffar, 2016; Pollock and Hyysalo, 2014). Second, users are part of "cacophony management": forging consensus among the conflicting preferences found within the clientele (e.g. about what ought to become general features (Hyysalo and Lehenkari, 2003; Mozaffar, 2016)). Third, users are involved in witnessing and consenting to development directions elevated as strategic, and thus imperative, for the vendor (Hyysalo and Hakkarainen, 2014; Johnson et al., 2014a; Mozaffar, 2016; Pollock and Williams, 2008). Indeed vendors of standard solutions have been forced to develop strategies to orchestrate their relationships with their user communities (Johnson, 2013; Johnson et al., 2014a).

Importantly, longitudinal biography studies show that categorising innovation as being either by the user or by the manufacturer is in many cases misleading. Most innovation processes have a shifting locus of innovation regardless of whether they started from users or producers. Biographies of innovation tend to be long and winding journeys rather than a clear one time-space event. In many cases, an adequate register would be to talk about user *contributions* to innovation rather than contrasting user (i.e. "user innovation") and manufacturer innovation (Johnson et al., 2014b; Hyysalo, 2009; 2010; Hyysalo et al., 2016b; Pollock and Williams, 2008; Usenyuk et al., 2016). This is particularly pertinent given the ongoing mainstreaming of user involvement as a resource within innovation strategy rather than a means for empowerment (Hyysalo et al., 2016a). Instead of an "empowered user", the industry operates with "managed prosumers" e.g. efforts to produce productive users (Hyysalo et al., 2016a; Johnson et al., 2014a). These are users who are engaged in marketing, community building, forecasting and co-financing in addition to their contributions to design and usages (Mozaffar, 2016; Pollock and Hyysalo, 2014). Many users are not naïve either. They participate in technology development for various reasons, which are not limited to creating better technology. Rationales for involvement include gaining personal skills, getting their (technology or service) needs met, securing access and proximity to the vendor. The 'business of being a user' can reach further into strategies in affecting competitors and the interplay of different user sub-communities and longer development paths of products and services (Pollock and Hyysalo, 2014).

The observations of extended user involvement, range of roles and considerable amounts of design-in-use have resonated with and to some extent informed parallel development in design research, where approaches for extended co-design and infrastructuring have emerged. Some of the work had direct interactions with BOAP such as the *co-realization* approach, where the collaborative systems design is extended to the workplace after launch to engage in development once a system is "used in anger" and its various possibilities, limitations and organizational implications become clearer (Hartswood et al., 2002; Voss et al., 2009b). Similar ideas have then been picked up in extended co-design with and for communities of practice (Botero, 2013; Botero and Hyysalo, 2013). These approaches have recently blended in with *design for infrastructuring* (Buscher et al., 2009; Karasti and Baker, 2004; Karasti et al., 2010; Pipek & Wulf, 2009) seeking to create computer systems (or systems-of-systems) that can support the development of effective work practices and enhancements over a long period – again paralleling the BOAP study shift into knowledge infrastructures.

In sum, once the research design is extended to cover multiple loci and times in the technology's biography, the processes of and rationales for engaging users in innovation appear in new and considerably different light. Situated local use and generic design of a product are, in a more encompassing view, snapshots of the complex interplay of user and developer contributions in the protracted processes of innovation. We shall next move to examine the purport of this in conceptualisations of technology-user relations in STS.

### *Configuring the user vs. series of configurational movements*

Many early technology studies writers adopted from the sociology of science the idea of 'closure' of meaning and stabilisation of form (Bijker and Pinch, 1984; Latour, 1987). The success of technology was treated as an outcome of efforts to enrol the relevant stakeholder groups in accepting what the appropriate form and meanings given to technology would be. If all the work—including standardisation; black-boxing of functionality; integrating the technology into wider systems; and creating markets, practices, and distribution—achieved its mark, the network supporting the technology would be hard to reverse, also making the success of the technology appear inevitable in retrospect (Bijker, 1995; Callon, 1991; Latour, 1987).

Various concepts were coined to address closure as well as the opening up of technology. "Configuring the user" attempted to describe how designers built 'the user' into technology in ways that favoured enactment of only certain kinds of uses and users (Grint and Woolgar, 1997; Woolgar, 1991). 'Domestication' conversely addressed how the form and meaning of new technology were altered when it was placed in contexts of use with their own pre-existing social and moral order (Silverstone et al., 1992; Sørensen, 1996). Inscription, prescription, and users' subscription or de-inscription conceptualised the interplay between the efforts of designers and of users in crafting and making their own reading of technology design and use in ways analogous to author/readers of the script of a play (Akrich, 1992; Akrich and Latour, 1992; Latour / Johnson, 1988).

The extended research designs across BOAP studies show that instances where overly zealous developers succeeding in mechanistically configuring the user (a la Woolgar) are rather exceptional. When observed at more length, such configuration goals are often complemented by arrangements geared towards enticing users into using technology, assessing their responses to new technology, and articulating their preferences and getting them represented in design (Johnson et al., 2014a; Mozaffar, 2016; Pollock and Hyysalo, 2014). BOAP studies do not suggest, however, a wholesale dismissal of Woolgar's concern with how design may seek to prefigure users and use. It is a good starting point but requires a conceptual shift towards viewing technology developer-user relations not as discrete episodes but as a *series of configurational movements*. There is the gradual and continuous shaping of technology that takes place in multiple arenas and modes in the life of technology, con-figuring things together into assemblies and capabilities for action and actors becoming included in its story, in the biography of technology.

Our conceptualization of technology development and user–developer relations is more detailed and extensive than innovation studies concepts such as "interactive model of innovation" by Freeman (1979) involving supplier-user coupling and "learning by interacting" (Lundvall and Vinding, 2005) or in the widely adopted STS terminology of "mutual adaptation" of technology and organization (Leonard-Barton, 1988; McLaughlin et al., 1999). Indeed these generic conceptualisations may be argued to act as what could be called 'cloaking metaphors' in that they flag the need to get inside the process, but are used as a promissory substitute for this analysis (for similar arguments regarding cloaking in such models and ensuing erroneous results see Miettinen, 2002; Scott-Kemmis and Bell, 2010; Tyre and Von Hippel, 1996). The more technical usage of 'configuration' retains the sense of the many elements being figured together, while resisting connotations of a unified and universal entity that might be implied by terminologies of a system, object, or artefact (Fleck, 1988, 1993). This is particularly relevant in characterising complex technologies such as ICT in equally complex organisational settings. Many aspects of configurations reach temporary closure and become more difficult to reverse. *Pre-configuration* among designers tends to reflect some closure of meaning and stabilisation of form among them. Pre-configurations among users include, but are not limited to, procedures, routines, norms, conventions of artifact usage, and patterns in implementing new technologies. Other typical pre-configurations are those of regulators and institutions connected to a particular kind of technology or domain of users. Any closure or stabilisation reached only among partial constituencies (whether of designers, users, or third parties) tends to remain limited in time and in space. Technological configurations are routinely subject to *de-configuring*, altering and questioning the technology, extant ways of practising and regulation. They are also regularly subject to *reconfiguring*: connecting, adding in, repurposing, omitting, and creating new solutions that change the shape of the socio-technical configuration. Importantly, these moments blend in with above noted active forms of *co-configuring technologies and practices* along the more or less contested sets of developer-user relations, and passive co-configuring such as acceptance of shortcomings, silencing of some of the problems, agreeing to defer changes et cetera. (Helgesson and Kjellberg, 2006; Hyysalo, 2010).

The analytical focus upon series of configurational movements is not merely of value in exploring designer-user relations but can be more broadly applied to a number of actor strategies in the course of distributed innovation processes. Actors have limited capacity to engage across temporally and spatially wide-reaching (indeed, potentially unbounded) interaction processes and, instead, make a series of partial interventions within their span of control and relevance. For example, industry analysts like Gartner have a strategic position in making the market, but this is a fragile achievement rooted in their ability to retain cognitive authority - something they must do again and again across multiple fields (Pollock and Williams, 2016). There are no guarantees as to the power of their position and, in contrast to the immutability implied in ANT terminology of *Obligatory Passage Points*, they have to retain their position vis a vis other sources of knowledge within the continually transforming industry field (ibid).

The ability to follow technology over long-term whilst zooming-in on key moments thus flags the generative nature of partial closures and stabilizations. These appear equally requisite for 'success' and 'failure'. As Pollock and Williams (2008) note, "if a supplier like SAP has succeeded in conquering the world, it did so one sector at a time, carefully, in a process characterised by setbacks and 'reversals'."

### ***The high(er than expected) prevalence of innofusion***

Tracing the series of configurational movements across studies has also come to highlight the importance and higher prevalence of phenomena that had been seen as exceptions. The notion of *innofusion* e.g. the blending of innovation and diffusion in the evolution of new technology (Fleck, 1988, 1993) is one of these. Innofusion was first observed in industrial robotics in the 1980s (Fleck, 1988, 1993), where a purportedly general purpose technology (robotics) had to be tailored and further developed for specific purposes at the sites of use. This further development work was shared between the vendors and customers and allowed the robotics technology to establish useful applications. Despite its clear contribution to improving the technology, innofusion was often not planned or wanted by developers or users. Neither party expected they would need to invest further development efforts in a seemingly ready technology.

Innofusion fell off the conceptual radar in both Innovation Studies and STS or was portrayed as simply characterizing a specific development context and time. This appears to have been, however, an artefact of methodological preferences: Innovation studies scholars preferred to conduct studies of innovations at a lower level of resolution than is needed for innofusion to become apparent, while the prevalence of single site studies occluded the phenomenon from STS and qualitative information systems researchers. In BOAP studies, however, innofusion appears common and to take multiple different forms. *Unwanted 'accidental' innofusion* akin to Fleck's original study has been documented in many settings including multimedia (Williams et al., 2005), health care applications (Hyysalo, 2010; Hyysalo and Hakkarainen, 2014), renewable home heating technologies (Hyysalo et al., 2013a, 2013b; Heiskanen et al., 2014).

But other forms innofusion processes have also been identified. Complex enterprise software packages featured similar dynamics. However in this setting, rather than disorganised innofusion, vendors had devised whole repertoires for handling it (Pollock and Williams, 2008). This pattern of *managed innofusion* has been since found in packaged software more widely: among different ERP/CRM vendors (Mozaffar, 2016; Mozaffar et al., 2015; Wang, 2007), logistics software (Wiegel, 2016), and health record systems (Hyysalo and Lehenkari, 2002, 2003). Similar mechanisms arise in collaborative development arrangements such as living labs (Hakkarainen and Hyysalo, 2013, 2016; Hyysalo and Hakkarainen, 2014) and long-term co-creative design where the development effort is purposefully arranged to happen at real user sites (Botero and Hyysalo, 2013, Hartswood et al., 2002).

In 'perpetual beta' digital service development strategies there is further intensification, *a planned innofusion,* where innofusion is taken as the core organising principle for service development. No longer being orchestrated for each new customer segment at the time, short release cycles are used throughout to adjust the service to emerging usage directions, peer content creations and changes in customer base (Johnson, 2013; Johnson et al., 2014b).

Finally, studies on user's innovative activities show that *dispersed innofusion* may also remain an effective, albeit not necessarily very efficient, innovation dynamic in cases where no developer company/community takes charge of coordinating, re-integration and generification of site specific adaptations by users. Usenyuk's study of user designed ultra-light arctic vehicles shows how highly site specific construction 'proximal design', a thorough blending of innovation and diffusion, can result in gradual elaboration of construction principles and emergence of a widespread complex class of technology (Hyysalo and Usenyuk, 2015; Usenyuk et al., 2016). Even in such dispersed cases, various interaction arenas and repositories of knowledge were needed for innovation to proceed across sites.

To sum up this section, research design and methodology choices affect greatly the conceptual models and empirical understanding of studied phenomena. Through the example of user involvement in innovation we illustrated how localist studies have maintained limited and outdated views of the roles that users play in innovation; how the extended research designs of the biography approach suggest new conceptual synthesis that is able to intertwine key insights from detailed studies to long-term processual views of innovation; and how methodological choices are not relevant only in the elaboration of new concepts but in assessing the relevance (or otherwise) of existing ones as the case of innofusion suggests.

## Conclusions

Together with other scholars, we have argued that science and technology are inconveniently structured for many of the analytical templates deployed by STS scholars (Hine, 2007). Studies limited to single or a few sites and times in the shaping of technology have become popular in STS, shaped on the one hand by pragmatic constraints of project funding and duration and on the other by the localist turn and the effectiveness of ethnographic methods in eliciting practitioners' understandings.

The reluctance of STS scholars to discuss issues of research design and practice has allowed the adoption of simplified research designs involving narrowly framed field studies (or conversely, broad-stroke historical descriptions). However, STS needs to move given its historical scepticism towards 'method' (Latour and Woolgar, 1979) if it is to continue to apply its insights to wider domains (Golinski, 1998).

There is the need for studies that not only drill down into the detail of settings, but, at the same time, pay attention to the long time spans of technological development. We remain sceptical regarding the practical forms of guidance that current templates provide for researchers about how to address technologies across multiple levels and time frames. Without the analytical cues as to the important sites and settings for investigation, encompassing the broader context as well as immediate sites of interaction, we find ourselves encouraged towards one or other type of (narrow) research design.

Whilst empirically focusing on single settings or moments has provided resources for some of the important narratives favoured by STS scholars, they have (more unhelpfully) created *framing effects*. This fragmentation and framing of enquiry has consequences. It (more or less drastically) limits our understanding of the workings of technoscience, and runs the risk of generating reduced forms of analysis. We have identified a number of failings of interpretation that arise, for example, both in our own work and that of STS scholars more generally, when studies embrace one or other mode of study and neglect immediate or historical processes. These may be adequate for understanding simple social interactions (as exemplified by Woolgar's (1991) 'configuring the user' study) but have serious drawbacks in grappling with the multiple interconnections of modern societies arising in particular from globally integrated technological systems.

The BOAP approach was borne as a response to this problem. It argues for greater thought to be given to more adequate methodologies and research designs capable of dealing with the complex phenomena under investigation. BOAP provides the means to explore, rather than take for granted, the different actors and factors in the course of the social shaping of technology. Let us be clear. We are not suggesting the capture of the *full* range of actors and factors involved in the biography of a technology. This would not be feasible let alone desirable. But we are clearly saying that not capturing the full range of actors does not entail that whatever goes. In practice, research can only unevenly and incompletely approach the ideal of covering all the key sites and their interrelations. Every research design involves choices about where to address research effort. New sites and relations become visible in the course of fieldwork. What we have illustrated is how STS as a field may require more awareness to what approaches it uses to encourage decisions (and compromises) about which black boxes to open for detailed examination and those which are to be left unexplored. This calls for flexibility in research design coupled with the willingness to keep on pursuing the line of investigation beyond the single setting and project funding.

No method or framework is without limitations. The analytical template of biographies of artifacts and practices set out in these pages is not easy or without challenges. When first introduced to these ideas, scholars often respond that the ideal of addressing multiple sites and temporalities is admirable but impossible to achieve. It can also be potentially demoralising, indeed inhibiting for those moving into a new research field within time and resource constraints. Our own experience runs to the contrary. More encompassing research designs are doable if one takes it as a long term goal and not a rigid one-off requirement for a specific research project. As part of this we argue for a move from snap shots to the linking together of a *string of studies*. This would be to knit together different kinds of evidence—that includes historical studies, ethnographic research, qualitative studies of local, and broader development. While BOAP investigations may start with specific discrete studies, with a limited scope, they will be conducted with an awareness of how a more robust understanding might be achieved by addressing a wider number and range of settings and extended temporal framing. Attempts to expand the empirical scope must confront pragmatic constraints of gaining access to different sites, the availability of respondents and documentary materials, the timing and pacing of developments being studied, the limitations of typical research projects and difficulties securing funding for follow-up studies, etc. Overcoming these constraints may call for a group effort, bringing together multiple researchers to work on different sites and times to more overarching depiction of the phenomena under study.

Finally, a small reflection on the domains in which one needs such complex methodological templates. BOAP emerged in research on information infrastructures and health technologies, characterized by the complexity of technology development, implementation and use. It has subsequently been successfully and fruitfully applied to a range of settings, technological forms and moments of innovation from Arctic sledges and South American Narco Submarines to automotive manufacturing systems and teenage virtual worlds. The BOAP approach suggests a need to adjust the specific research strategy within the approach according to the sociomaterial form of the technologies and practices being studied and also the foci selected. Developing further the repertoire of specific strategies for different settings is methodological work-in-progress. This all is to say, as convenient snap-shot studies may be, we suggest it is time to move beyond single focus studies in STS and open up for reflexive discussion wider repertoires of research design. This paper seeks to open up this debate.

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# **The Factish in the Field:** An Anthropological Inquiry of Genetically Modified Seeds and Yields as Beings

*Andrew Flachs*

*Department of Anthropology, Purdue University, USA /aflachs@purdue.edu*

## Abstract

Research in GM crops is of pressing importance to biotechnologists, development economists, farmers, government officials, and concerned citizens. Each of these stakeholders carries preconceived notions of success and failure that not only influence how data regarding GM crops is shared but also reify the objective reality of GM seeds as a technology that might exist outside the idiosyncrasies of a farmer's field. In this essay, I draw on ethnographic fieldwork conducted among GM cotton planting farmers in Telangana, India to deconstruct the process by which scientific facts surrounding yields and GM seeds are created, leveraged, and then divorced from their subjective contexts in agricultural research. Calling attention to the methods and assumptions involved in constructing scientific facts, Science and Technology Studies (STS) reveals underlying complexities that explain why purportedly objective science, and the seed as its supposedly universal product, produce such ambiguous outcomes for Indian farmers. Specifically, Isabelle Stengers' and Bruno Latour's notion of the factish, the process by which autonomous facts are created and live beyond their experimental and laboratory confines, can help to explore the neocolonial dynamics underlying the construction of success and failure in GM crops.

**Keywords:** agriculture, biotechnology, anthropology, factish, India

## Introduction

"Don't you understand," my research assistant asked after a particularly long and difficult interview. "We're taking a lot of their time, don't you see? If we were not here, they would not be answering any questions and giving any of this information for your study! They're only giving this information because you're asking." I conducted 14 months of ethnographic fieldwork 2012-2016 among farmers in Telangana, India, planting genetically modified (GM) Bt[1] cotton. Through this anthropological inquiry, I sought to understand how farmers made decisions about the seeds they planted. Although I set out to administer surveys and interviews that asked farmers to justify seed choices and report their yields, these data do not exist independently of the specific farmers, conditions of the field, and the space of the interview. Frequently black-boxed in academic literature, yields and seed choices cannot be understood apart from the farmers who grow them, the fields in which they grow, or the scientific processes used to discover this knowledge.

My assistant's question speaks to a deeper concern with the institution of social science.

A social science researcher's questions and respondent answers exist within the occasionally awkward space of the qualitative interview. Aided by a research assistant, I ask questions relating to seed choices, yields, and farmer experiences with agricultural technologies. Such interviews range from twenty minutes to two hours, depending on our shared patience and the meandering route of our conversation. Sitting in plastic lawn chairs drinking sweetened tea we are separated not only by race, class, education, language, culture, and history, but also the assumptions of research that demand that farmers have answers to questions about their decision-making. In practice, farmers often do not remember the names of their seeds, cannot clearly describe their crop yields, and do not express their motivations in clear, linear ways. While frustrating, this breakdown of knowledge and miscommunication between American agricultural companies and Indian farmers is a crucial part of my research in the experience of new seed technologies. My research assistant is correct to observe that my investigations and subsequent database of seeds and yields is determined by the constructed space of the interview. There, farmers, research assistants, anthropologists, and seeds co-create a narrative appropriate for academic research, but that does not exist as a truth external to any of us.

In February 2013 crop scientists observed that GM cotton yields hit a five-year low in India, leading media and activists to declare GM crops a failure (Jha, 2013; Nair, 2013). Six months later, national newspapers cited scientific studies to claim that the same cotton increased yield, increased incomes, and helped to develop the nation (The Economic Times, 2013a; The Hindu, 2013). In this essay, I argue that there is no truth to seeds or the yields they provide that exists apart from the specific people who cultivate GM crops and the farms where they grow. By calling attention to the methods and assumptions involved in constructing scientific facts, Science and Technology Studies (STS) is uniquely positioned to explore the underlying complexities that explain why purportedly objective science, and the seed as its supposedly universal product, produce such ambiguous outcomes for Indian farmers. Specifically, Isabelle Stengers' and Bruno Latour's notion of the *factish*, the process by which autonomous facts are created and live beyond their experimental and laboratory confines (Latour, 2010b; Stengers, 2010, 2011), can help to explore the neocolonial dynamics underlying the construction of success and failure in GM crops.

This paper begins by looking to the actors and processes involved in constructing scientific narratives about agricultural development. Then, I adapt the factish as a heuristic to understand how yield became the yardstick by which agricultural development should be measured and how seeds take on a life of their own in development studies, independent even of the farmers who grow them. This leads me to discuss the politics of measurement, but I stay with the factish as a conceptual framework because it draws attention to the ways that scientific facts, here seeds and yields, come to have independent lives in agricultural scholarship and policy. GM seed debates are currently framed around yields, and understanding how arguments in favor of or critical of the spread of GM crops in the developing world rely on this discourse without questioning its underlying assumptions helps untangle plural lived experiences with this new technology. I draw on debates relating to GM crops in India, including reflections on my own ethnographic fieldwork 2012-2016 and my reading of key authors from agricultural economics, anthropology, public policy, agronomy, and crop sciences. In paying closer attention to the ways that the science of agricultural development has circumscribed the possibilities of farmer experience, this paper addresses Latour's (2010a) call for a compositionist investigation of a shared world slowly assembled by its constituent actors. Because I am analyzing this research within the scope of STS, I will critically examine the methods and assumptions of several researchers and disciplines. However, I myself have employed the same tools and used the same factishes to make arguments about Indian agriculture. In this essay I intend not to criticize these methods or scientists but to illuminate the ways in which we all have described seeds and yields as autonomous beings.

## Debates and contested scholarship in GM research in India

All scientific research is contextualized within the paradigms that guide researchers' questions and research design, as well as within subtler biases inherent to the tools used in different disciplines. This is a function of the larger sociology of science that determines which questions are asked, by whom, and how scientists judge the evidence they collect. In agricultural development research, this issue is complicated by the pervasive influence of pro-GM and anti-GM voices that conduct scientific research as members of industry research groups or activist Non-Governmental Organizations (NGOs), respectively.

In India, GM crops have been alternately celebrated as a pro-poor technology raising incomes and yields while decreasing pesticide sprays (Herring, 2007; Kathage and Qaim, 2012; Veettil et al., 2016), or derided as a dangerous incursion into Indian agriculture failing small farmers (Nair, 2013; Shiva et al., 2002). The direct causal relationships between Bt cotton, cotton yields, and farmer well-being remain difficult to parse away from pro- or anti-industry sentiment (Stone, 2002). In India, these relationships are measured by proxy benchmarks for success, such as farmer enthusiasm or the nation's total cotton production. Over 95% of Indian farmers have adopted Bt cotton since its official 2002 release (Cotton Corporation of India Ltd., 2014), a figure that agricultural scientists (Herring and Rao, 2012; Kathage and Qaim, 2012) and government officials creating policy (Cotton Corporation of India Ltd., 2014; The Hindu, 2013) cite as proof that farmers have eagerly chosen Bt cotton. The language of choice posits that farmers make choices in a rational and free market, where they objectively evaluate seeds as yield-producing commodities.

On Telangana farms, free and informed choice is often difficult to achieve. Although economists and policymakers celebrate GM seed adoption as a choice in a free market, locally desired seeds are often unavailable and villages are plagued by periodic shortages of popular brands (Wadke, 2012) or spurious seeds (Herring, 2007). Yet the framing of seeds as a matter of freedom and choice (The Economic Times, 2013b) helps these pro-GM voices explain away other research with more ambiguous results regarding farmer inputs. Longer-term studies on the effects of Bt cotton in India challenge the influence of Bt cotton on higher yields and lower pesticide sprays (Gruère and Sengupta, 2011; Stone, 2013), attributing these to changes in agricultural management strategies like new pesticides, fertilizers, and denser planting (Gruère and Sun, 2012; Stone, 2011). Additionally, while pesticide applications initially fell with the introduction of Bt cotton on Indian farms, a key benefit of Bt cotton (Veettil et al., 2016), insecticide sprays in Indian cotton now exceed pre-GM levels (Kranthi, 2014).

Examining pro- and anti-GM research as texts, Pearson (2006) argues "that there are striking similarities in the narratives utilized by both Monsanto *and* [anti-GM NGO] Deccan Development Society; both seek to deploy 'objective science' in their efforts to govern smallholder farmers, and both purport to represent transparently the views of farmers and their best interests" (Pearson, 2006: 307), emphasis in original). Both GM companies and critical NGOs continue to release studies claiming that Bt or non-Bt cotton, respectively, is more profitable, socially sustainable, productive, or ecological for farmers. Agribusiness companies have an obvious interest in showing that their products are successful, defined through Monsanto India's (2012) and the Cotton Corporation of India's (2014) annual reports that celebrate Indian farmers' aggressive adoption of GM cotton. However, environmentalist groups also benefit from upticks in funding when stakeholders rally behind anti-GMO sentiment (Schmid, 2007; Schurman and Munro, 2010). Schurman and Munro (2010) further argue that pro- and anti-GM activists and institutions inhabit fundamentally different 'lifeworlds', the norms that define values and ideas while structuring interactions, guiding their differing interpretation of the same evidence.

Whether supportive, critical, or agnostic, this body of research focuses on seeds and yields as indicators of success and failure. While not contesting the underlying claim that seeds' yields can be measured independently of the conditions under which they are grown, critics (Crost et al., 2007; Gruère and Sun, 2012; Stone, 2011) attack empirical studies of Indian GM crops as relying on flawed farmer samples. These critiques charge that others irresponsibly generalize from the field trials of seeds planted by the wealthiest, most adventurous, and highest yielding farmers. Empirical trials of GM crops suffer from a selection bias in the farmer sample as a whole, they argue, and are therefore a poor indicator of the broader impacts of GM crops. Social scientists have noted that the earliest adopters of any technology are likely to have more resources and to be more cosmopolitan than others in the community (Rogers, 2003; Ryan and Gross, 1943), because the institutional support given to such early adopters can help to underwrite the costs of using new technology (Stone, 2016). Critical researchers agree that yields can and should be measured, but they disagree on whose yields are most representative.

Agricultural economist Matin Qaim (2012), who has published numerous papers in top journals on the effects of Bt cotton in India, aimed to refute this sampling critique through a 2012 paper that used stratified stratified economic models. These document farmer experiences across a representative swath of socioeconomic variation, countering farmer selection bias 2002-2008. Yet this was too little too late, argued anthropologist Glenn Stone (2012), who observed that success narratives had already been established by initial selection biases and short-term research designs (Stone and Flachs, 2014). Stone argued that these early results allowed pro-GM findings, already exciting and thus attractive to academic journals, to flow through publication pipelines as the studies cited each other and established a circular credibility. Questioning the incentives of academic publishing and the sampling strategies of agricultural economists, Stone (2013) cites his own ethnographic research as proof of his commitment to discovering facts on the ground – a criticism not of the process of scientific inquiry but an argument for better models that account for the complexity of agricultural work.

Stone's appeal to an objective empirical science fueled a 2012-13 debate through the widely read Indian intellectual weekly journal, Economic and Political Weekly (Herring, 2013; Herring and Rao, 2012). While conceding that some early studies may have been biased, Stone's agricultural economist interlocutors argued that each new study continued to build a scientific consensus that Bt cotton itself was responsible for increased crop yields in India. Agricultural economist Ronald Herring (2013: 63) responded wryly that the presumption that such research stems from collusion between GM manufacturers and scientists is a strong claim, "even by the standards of conspiracy theories". Citing Latour's (2003) *Promises of Constructivism* as an example of postmodernism at its most destructive to objective science, Herring asks if critics like Stone would consider facts to be socially constructed fiction (Herring, 2013: 63). Ironically, Latour laments in that essay that constructivism has been misused to present a false equivalency between scientific arguments and personal opinions. This misses his arguments about constructivism, which questions not facts themselves so much as the way that scientists tend to remove themselves from their findings. Latour argues instead that scientific facts are made real through the process of scientific inquiry, not discovered in a state of nature by objective scientists.

## Obligations and Responsibilities in Agricultural Development

The authors and institutions above may disagree on the interpretation or collection of yield and farmer livelihood data, but each situates their claims within a scientific process that discovers objective data. Their argumentation presupposes a truth, Bt cotton yields, that waits to be discovered. This is opposed to a Latourian (2010a) compositionist approach that would see scientific facts as mutually composed by different stakeholders and inextricable from that context. The focus on yield and productivity, even by critics challenging the success of GM crops in India (Forster et al., 2013; Gruère and Sun, 2012; Jha, 2013), masks the contingencies of agriculture and the construction of a scientific space in which to measure yields. In effect, both scholarship critical of and in support of GM crops as a form of agricultural development in India employ the same types of abstract reductions when describing yields and seeds. This presents an opportunity for an STS analysis of the underlying assumption in this research: that seeds and yields exist apart from farms, farmers, seed shops, GM regulations, weather, agricultural researchers, and the multitude of other stakeholders involved in rural life.

That a seed cannot have a yield unless it is grown and measured may seem obvious to STS scholars, but it is curiously absent from the dominant discussions by agronomists, policymakers, economists, and even sometimes from ethnographers like myself. The seeds are viewed as if they have the power to create yields and justify policy irrespective of who plants them or how. This is a vision of seed technology and the measurement of yields as an autonomous thing beyond and independent of the people and social institutions that interact with it – a *factish*. Qualitative social scientists problematize the definitions of facts on the ground in their analyses of experience (Herring, 2007; Stone, 2011), calling attention to the diverse and complex ways that farmers make cost-benefit decisions or even how they calculate yields on a plant like cotton that will provide multiple harvests throughout it growing season. Yet when articulating their findings with a broader debate within agricultural development, they more often frame their arguments within the scope of the yield and seed as if those were inherent truths lying in wait to be discovered. In this way, qualitative social scientists simplify some aspects of their work to make it legible to this wider audience.

This simplification is unfortunate, because an empirical and STS-inclined analysis suggests that there is no singular narrative driving neo-colonial relationships in agricultural development. Instead, as I will discuss below, there are several competing definitions of yield and several competing understandings of success and failure discussed by scientists, policymakers, trade analysts, or farmers themselves. During interviews, farmers claimed to be switching seeds in the search for good yields (Telugu: *manci digubadi*), but this measure of 'good' rarely translated into a reliable cost-benefit analysis that one seed would yield more than another or experience a more profitable response to fertilizers or pesticides (Flachs, 2016). Instead, farmers spoke about yields as a way to show off their skill to neighbors, scientists, or other passersby. Noticing a neighbor spraying his fields, one farmer cut an interview short by saying that he had to go spray as well. "Do you have insects in your field," I asked. "No," my interlocutor admitted. Nevertheless, "you should always seek to produce more than your neighbors. If they spray four times, you have to spray five." Yield here is as much a competitive signal as it is a search for an objective profit. Later, when I spoke with a local crop scientist, he reiterated the factish argument that yields are inherent products of the seeds, not complex efforts on the part of farmers and fields. "Here farmers are very intelligent," he said. "If [a seed] performs well they'll keep going with that hybrid. Otherwise they'll throw in the dustbin." By reducing the decisions and farmer experiences with seeds to a question of intelligence or yield calculations, the scientist sidesteps other possible competing understandings of how farmers select seeds or measure yields while simultaneously attributing yield as a product of the seed, not of farmers' efforts.

Latour's (2010b) and Stenger's (2010, 2011) analysis of the factish can help to engage these deeper questions because they illuminate the process by which subject and object are ostensibly separated in scientific inquiry. In calling attention to the ways in which facts are composed as scientists conduct their work, the factish can be a powerful tool to analyze how arguments are conceived in the space of the field test-plot or the farmer interview. Factishes also emerge when farmer yields are considered in aggregate, as when researchers (Cotton Corporation of India Ltd., 2014; Lalitha and Viswanathan, 2015) characterize yields produced not by Indian farmers, but by India itself.

Agricultural economics and anthropology, like all sciences, exist within what Stengers (2010) calls an ecology of practices. Ecology, Stengers argues, is an advantageous metaphor because it has both scientific and political connotations. Ecological science stresses the interdependence of subjects and objects, and helps Stengers to work against a view of facts that exist as naturally occurring objects waiting to be discovered. Politically, ecology also emphasizes that not all environments provide equal opportunities for those subjects and objects. Stengers (2010: 32–34), argues that science as an ecology of practices illuminates unexpected symbioses and unintentional creations of meaning. While she uses this term to mean that what science discovers cannot be separated from how scientists discover it, a key insight of STS itself, she continues that this process also creates requirements and obligations, an ecological link between knowledge and the thing discovered.

This set of obligations and requirements is self-reinforcing in scientific practice, what Stengers (2010) terms a reciprocal capture. Scientists and their objects of discovery come to work together symbiotically when scientists construct research spaces like test fields or farmer interviews, thereby reinforcing the objective of looking for or experimenting on something in the first place. Reciprocal captures also illustrate the potential asymmetry of scientific inquiry. Stengers cites ecological examples like parasites and predators as reciprocal capturers, who create value and knowledge in an ecosystem and who do not exist apart from each other. These interactions need not carry such negative connotations. Stengers (2010) continues to explain that neutrinos and physicists also engage in an asymmetrical reciprocal capture of obligations and requirements. Neutrinos, difficult to stabilize and observe in a laboratory, must be made to exist for the physicists who study them. Through this process, the physicists themselves change, understanding themselves and their work within the questions and speculations made possible by the neutrinos. Ecologically, they are linked even though scientists more directly forge the connection. Thus is the capture reciprocal.

The ecology of seeds and yields from this perspective includes the need for seeds to grow, rain to fall, and soil to bring forth plants, but also for governments to allow GM legislation, seed shops to carry the desired brands, and scientists and farmers to record yields. Seeds and yields do not exist outside of the narrow set of conditions in the political economy that bring them to farmers' fields. Indian cotton farmers, like Stengers' neutrino physicists, come to see themselves with respect to their ability to produce good yields, a reciprocal capture framed within the logics of agricultural development that limits other possible visions of agricultural success. Farmwork, like physics, creates conditions through its ecology of practices that lead farmers to see themselves as protectors of plants (Gupta, 1998), stewards of soil (Stoll, 2002), and otherwise fundamentally moral caretakers (Pandian, 2009) who create landscapes and increase yields. To unpack the factish on the field, I will first clarify the processes used in anthropological, economic, and agronomic inquiries into GM crops.

## Latour, Stengers, and Three Types of Factish

In agricultural development science, encompassing social scientists, agricultural economists, and agronomists, yields and seeds have been given lives unencumbered by farms and fields – thus can Bt cotton be credited with increasing yields or changing farmers' lives in India as discussed above. Farmers, scientists, and seeds have been swept up in the factish. Latour began exploring the construction of scientific facts in Laboratory Life (Latour, 1986), an ethnographic study of the way in which scientists and laboratories produce scientific texts. These texts coalesce to reveal universal truths, but through the process of their creation, they are often contested at certain moments. Impossible to attribute to single authors, Latour found that they are created by a wide range of actors seeking consensus throughout the process of scientific inquiry. The resultant actor network theory later helped him investigate how various agents create a mutually composed reality within institutions such as the economy, science, or religion (Latour, 2003).

This ultimately leads Latour (2010b) to describe the construction of *subjects* much as he previously observed the construction of *objects*. Throughout *On the Modern Cult of the Factish Gods,* the titular factish concept emerges as a way to illuminate how beings transition from (1) the state of subjective human action enmeshed in a sociocultural web of meaning to (2) an autonomous being beyond and independent of the human actor. Factish is an etymological play on the term 'fetish', which derives from the Latin *facio*, to make. Portuguese traders living near Africa's Western coast denounced animist religious objects as fetishes, human-made and imbued with false power. This propelled a colonial legacy of distrusting fetishes as constructed from human beliefs and led "moderns", those who ascribe to a nature/culture separation, to distrust the notion that human beliefs creep into scientific facts. To trust facts, Latour (2010b) argues that moderns must both deny that they are constructed and create a space, such as a laboratory or a farmer interview, where facts can be reliably discovered. These spaces sustain the illusion of the separation between discovered object, process, and discoverer subject. By drawing attention to the social work that drives scientific inquiry in this work, Latour describes a factish as a subject in its own right, which facilitates the creation of autonomous facts.

In her second volume of *Cosmpolitics*, Stengers (2011) builds on Latour's factish to shed light on at least sixteen different gradations of the concept. I will collapse these into three broad categories for my analysis below. The theoretical factish is characterized by new ways of thinking that allow us to construct a reality in which researchers can ask different kinds of questions and imagine other paradigms. Theoretical factishes "intervene whenever theories "judge" experimental practices and refer to them as a reality that assigns them one role, that of access to its own – now discovered – theoretical truth" (Stengers, 2011: 78). Although scientific theories circumscribe findings by delineating an experimental process, theoretical factishes help to re-expand the pool of possibilities in scientific practice. Throughout *Cosmopolitics I* and *II*, Stengers (2010, 2011) cites individuals and paradigms that helped to enable a new way of representing real possibilities: new concepts of quantum physics required rethinking older models of Newtonian dynamics, while the equivalency reified by the "=" sign challenged extant ways of knowing. Because GM crop research in India is constrained by efforts to understand seeds and farms in terms of yields, a new theoretical factish would demand a new politics of measurement and analysis beyond a success defined by yields or comparisons of seeds planted.

Stengers' experimental factishes concern the construction of subjects like yields or seeds, which she describes as being at once constructed by humans and living their own existence (Stengers, 2011: 4). Similarly to the Latourian factish, the experimental factish gains power from a false autonomy derived from modernist illusions in scientific practice. An experimental factish interacts with living and nonliving agents in the world and its subsequent "adventures, once stabilized, [can be] "explained" in terms of the properties that have been attributed to it as an "autonomous being" (Stengers, 2011: 58). For moderns, this existence can be accepted because it can be tested (Stengers, 2011: 78). Latour (2010b) calls this a circular argument, used by moderns when they create a superficial divide between belief and empirical knowledge in the laboratory setting. As I will discuss below, seeds and yields are experimental factishes when they are made to exist unencumbered by the means of their cultivation or measurement.

Stenger's third flavor of factish induces a new kind of relationship between the laboratory and the larger world based in the self-interest of the scientist. This is the promise factish, which focuses on the possibilities exposed when the promise of a solution and the problem itself can be articulated and joined (Stengers, 2011: 246–7). The promise factish describes a process by which researchers formulate scientific processes and research questions in such a way that allows science as an institution to work around problematic assumptions. In this way it is similar to the theoretical factish. Unlike that variety, it does not emerge from a generic need for new theoretical possibilities. Rather, Stengers' promise factish makes a concerted effort to create a scientifically viable model capable of solving existing problems. In the current scientific discourse, yields represent such a promise factish in that agrarian development has been framed as referential to crop yields: yield is what development experts are concerned with studying, yields are contested as benchmarks, and the solution of higher yields is itself joined to the problem of underproduction without questioning the value of using that benchmark. No alternative futures are necessary in this promise factish framing – only higher-yielding seeds.

The factish is a useful heuristic to explore GM seeds, although it is only part of this complicated story. Factishes draw attention to the ways in which scientific inquiry creates facts, like crop yields, that appear to have their own, autonomous lives. Latour and Stengers stress that this heuristic focuses on scientific processes, but a focus on the factish itself may distract from the larger politics of measurement (Porter, 1996; Rottenburg and Merry, 2015), which ask why the quantification of data, such as yields, has become so important for states and corporations in the first place. Although there is not space in this manuscript to fully discuss the complex and politicized ways in which yield is measured, the urge to document yields as objective and naturally occurring truths distinct from their particular and socially constructed context in farmers' fields is essential to the larger debate over how GM crops affect the lives of smallholders. Because critics also frame their arguments around yields, either to say they are lower than reported or that the farmers in question have abnormally high yields, they too are participating in creating a factish that keeps yields distinct and separate from the innumerable variables of farm management, farmer and scientist measurement, and politicized reporting. Viewing social science research from a Stengersian, ecological perspective, yields are sustained by a promise factish that defines possible requirements and obligations of working with cotton farmers. The factish, a tool to illuminate assumptions and methods, shows how success and failure have become tied to crop yields as one factor above all others. The experimental factish in particular is useful in describing the material catalyst for the controversy: the GM seed itself.

## Facts and Factishes in Agricultural Development

Debates on the merits of GM crops in the WTO, across India's scientific and regulatory bodies, in popular discourse, and in scientific circles maintain that there is such a thing as a GM cotton seed. Yet this is not, strictly speaking, true on farms: Each seed is unique in size and shape; many seeds, as much as 25% of an acre packet, never germinate and leave field gaps filled with home vegetables (Flachs, 2015); each farmer has small variations in their land and resources allowing different seeds to have differential opportunities; the seeds have varying levels of genetically modified Bt gene expression; insect, weather, and weed patterns affect the crop; and several different versions of Bt expressing genetic constructs have been bred into more than 1,200 GM private seed brands. No single GM seed could stand in for all seeds in all situations. Social scientists (Herring, 2007; Stone, 2007) find that farmers are often unclear as to the differences between seed brands, an uncertainty common in studies of new agricultural technology (Busch et al., 1990; Tripp and Pal, 2000).

Law (2004) and Lury and Wakefield (2012) argue that social scientific researchers and their methods address this complexity by helping to create the world that they are meant to explain. While ethnographers may be comfortable with addressing their influence and positionality in reporting yields, scientists seeking more objective measures, including agricultural economists and agronomists, may be less comfortable in accounting for these socially constructed variables. In Stengersian terms, the degree to which the researcher's voice creeps into scientific documents reflects the different obligations that researchers using these distinct disciplinary approaches have to their data. This further muddies reports of yield as success in farm fields in the resulting scholarship. A search of the term "GMO factish" on GoogleScholar suggests the term "GMO facts". This is part of why I argue that the factish has an opportunity as a heuristic on these farms. Despite its usefulness in illuminating the circular logic of the practice of development science and the separation of seeds from farmers and institutions, this concept has yet to be widely incorporated into studies of agricultural development. However, the influence of sociopolitical institutions on what counts as acceptable science is a powerful force in GMO discourse.

States and supranational groups require different forms of evidence to evaluate GMOs through their regulatory structures, reflecting their conception of their relationship between states, scientists, and objective scientific inquiry. Sheila Jasanoff's (2005) study of comparative biotechnology regulation argues that the United States, the United Kingdom, and Germany developed unique regulations for the production and commercialization of GMOs based in their national conceptions of markets and legislation, food safety, and centralized state science, respectively. Similarly, The World Trade Organization (WTO), found that the requirements for scientific proof have led to regulatory difficulty across national borders (Bonneuil and Levidow, 2012). When adjudicating the spread of GM technology, the WTO demanded that scientists be able to produce objective and detached "views from nowhere" that could justify regulatory science without the perceived bias of pro- or anti-GM sentiment. However, WTO member states called for strict, science-based trade law without ever reaching consensus on what it meant to prove or disprove something scientifically, let alone a consensus on what it meant to practice science. The WTO attempted to sidestep state concerns about GM science by demanding that states produce experimental factishes, scientific evidence that would be separated from its human, and thus politically biased, connections. Ultimately, differing national burdens of proof and standards for scientific objectivity derailed GM crop trade policies between the Americas and Europe in the early 2000s (Charles, 2001).

The complex combination of enthusiasm and caution experienced by farmers, consumers, and regulators in the USA and Europe may have had rippling effects in attitudes toward GM crops in nations in Africa and Asia. Paarlberg (2001, 2002) argues that cautious approaches in Europe have led countries in the developing world to hesitate, caught between a suspicion of neocolonialism and the fear of missing out on new technology. Implying that Indian farmers would like to plant GM hybrid seeds but are being held up by burdensome regulation, Paarlberg further argues that seed-saving nations like India have benefitted from new private sector seed varieties bred to solve agricultural problems. India has been particularly Janus-faced with GM regulation, reflecting a desire to grow biotechnological capital, meet the needs of poor farmers, and resist domination by foreign influence (Guha, 2008; Scoones, 2006).

## The Promise Factish and Development Imaginaries

The WTO and global regulators presume that science, technology included, can be objective and that politics are separate and interfering in a natural process of economic growth. This is the promise factish, which posits that scientific practices can be reworked to keep old possibilities in place without suggesting new paradigms. In doing so, it maintains the existence of the experimental factish, which separates yields and seeds from scientific or agricultural actors so that they can be objectively judged. Such logic follows that GM seeds are only one thing: yield-improving. Similarly, a yield is only one thing: evidence of a farmer's competence. Within this narrative, all other interpretations of agriculture are political and anti-scientific. Perspectives driven by these larger discussions of agricultural development economics can be seen in pro-GM academic outlets like *AgBioForum*, although it is not out of the mainstream of scientific inquiry as discussed above. The contrary view, espoused by environmentalist authors like Vandana Shiva (Shiva et al., 2002) frames the argument similarly, but reaches a different conclusion. From this perspective, GM seeds are poisonous and dangerous while seed companies promote GM crops through objective corruption in the regulatory process. Much as the economics-driven national and supranational arguments hold that all alternative views are political because they are unscientific, this contrary national and supranational perspective holds that all other interpretations of agriculture are political because they are corrupted by agribusiness interests.

These arguments ignore that farmers are a heterogeneous group and yield is a tricky phenomenon to study. The promise factish common in agricultural development, that technology leads inevitably to a better state of higher production, compels pro-GM researchers to ask "why might it be that low income countries would apply regulatory systems for agricultural biotechnology modeled after European standards, *even though it means their poor farmers and consumers lose any potential gains in agricultural productivity and social welfare*?" (Graff et al., 2009: 1, my emphasis). The authors suggest that biotechnology free from regulation is a necessary precondition of agricultural productivity and its associated social values. This free-market approach celebrates small farmers' potential to earn greater returns through higher yields of a cash crop like Bt cotton, but ignores the longstanding suspicions that Indian farmers and regulators harbor against foreign technologies and influence (Parsai, 2012; Scoones, 2008). Such an argument is also apolitical in that it does not consider the colonial history that has led to India's complex regulatory framework. Instead, in this framing, technology offers gains in yields and incomes, with no discussion of the differences in trade, agriculture, or aspiration between those producing and consuming biotechnology.

Authors who accept this promise factish see development as the technological creation of higher-yielding seeds, where success is judged by the single metric of yield. This is true even of detractors like Shiva, who contest this argument by denying or downplaying measured gains in yields as evidence of GM crops' failure. In reworking agricultural development to fit the proscribed future of higher yields and better outcomes, the promise factish suggests critical and optimistic ways that GM crops affect farmers in developing countries: GM advocates and detractors alike appeal to a sense of justice based on equal access to technology (Graff et al., 2009; Paarlberg, 2002; Shiva et al., 2002); they argue that GMOs are necessary to or incapable of feeding and clothing the world sustainably (Altieri, 2005; Dreifus, 2008; Fedoroff, 2011; Qaim, 2010); and they bemoan the lack of scientific argumentation while suggesting that GM crops will assuage or exacerbate global issues of suicide, climate change, and population (Gutierrez et al., 2015; Harmon, 2014; Plewis, 2014).

## Seeds and Yields as Experimental Factishes

The experimental factish is far more pervasive and obvious than the other factishes in studies of GM research: the notion that GM seeds and the measurements of their yields are independent from the political economy and scientific practices in which they are embedded. Throughout regulatory battles over GM cotton in India, success and failure have been structured around questions of yield and agronomic success (Herring, 2015). This argument disembeds seeds from larger social or political connections and considers them to be autonomous beings. By framing legitimate criticism within the space of yields, Herring (2015) argues that Bt cotton advocates sidestepped issues of risk and biosecurity that later dogged Bt brinjal, which was slated to be India's second approved GM crop before national outcry placed a moratorium on all new GM crops in 2010 (Rodrigues, 2010). While agnostic on GM crops themselves, Herring notes that un-scientific concerns around Bt brinjal, based in public fears rather than agricultural science, have led to an un-scientific rejection of the crop. This conclusion is only possible when seeds are viewed as autonomous objects and yields as objective truths waiting to be discovered. Numerous (Fedoroff, 2011; Graff et al., 2009; Harmon, 2014; Paarlberg, 2001; Thaindian News, 2008) pro-GM scientists argue that biotech fear and farmer non-adoption stem from doubt manufactured by anti-GM groups mobilized to affect the risk-perception of uninformed people (Blancke et al., 2015). According to this factish, because crop yields can be objectively measured by scientists, a better informed public should have no such objections. But even the most hardened critics of constructed facticity admit to considerable variation in actual farm fields:

> "Bt produces one trait; it affects only biotic stress from one class of insects. Yields are driven by numerous traits, characteristics of germplasm, and biotic and abiotic stresses that vary continually. There will be variance, field to-field, season-to-season. Variance across studies simply reflects the nature of agriculture." (Herring, 2013: 64)

Yield, Herring shows, is inherently complicated because it results from innumerable variables in the practice of farmwork. And yet to make arguments about yield and the efficacy of seeds, Herring and other agricultural development writers including myself (Flachs, 2016; Gutierrez et al., 2015; Stone, 2011) must accept the experimental factish that they can reliably measure and report those yields in aggregate. Adding considerations like weather and social stratification helps them to maintain belief in the factish, that seeds can be abstracted and studied as external to farmers and fields even when confronted with empirical realities or lived experiences that do not match the expectations of the factish.

The socially constructed conditions under which seeds and yields are measured enable experimental factishes like the neutrinos or microbes studied by other STS scholars. In my own measurements of yields and discussions with agricultural scientists in Telangana, I found that yields and other production analyses are often context dependent. Cotton will fruit several times over the course of a season and is picked, with diminishing returns, two to ten times per season. Scientific arguments over systemic bias in yield measurement have been addressed above, but both sides maintain that there is an interior truth, a true yield that can be discovered.

The search for a composed social reality regarding yields is easier on the scale of anthropology, typically requiring years of language training and long-term fieldwork with relatively small populations, than on the scale of agricultural economics. Qaim and Zilberman (2003) based their initial findings on panel surveys with 157 farmers in 25 districts in three states, and used this to argue that GM crops were a success and should be spread in other countries in the global South. Qaim's team has used this panel data to conduct long-term studies, an innovative mixed-methods approach to agricultural economics data, revealing interesting trends about adoption, risk, and decision-making not usually legible to agricultural economic studies (Kathage and Qaim, 2012; Kouser and Qaim, 2011). Yet other disciplines have different requirements and obligations in the collection of their data.

I personally surveyed Bt cotton-planting farmers in three districts in one region of one state and found ambiguous results for yield, inputs, seed responses, and metrics underlying agricultural decisions on farmer fields (Stone et al., 2014). I used a recent census to identify at least 60 farming households in each of six villages (resulting in nearly 400 households surveyed), stratified into three wealth terciles and selected to represent a range of variation in soil quality, ethnicity, and proximity to cities. Furthermore, I used this survey as the first step in a larger ethnographic interview in which I was able to spend time speaking and sometimes farming alongside farmers to collect richer qualitative data. Ultimately, I spent 14 months collecting this data with farmers, including repeat visits and numerous walks around the field.

This ethnographic approach differs from the short-term visits, structured surveys, and occasional focus groups of the agricultural economics studies above, and thus allowed me to collect different data. While farmers justify their seed choices with the hope for a greater yield over another seed, I found that this hope does not manifest in greater yields with different seeds when I asked farmers to report their yields over four consecutive cotton seasons 2012-2016. I am not comfortable generalizing beyond the region where I worked because anthropologists place a primacy on hyper-local knowledge and practice, while economists likely would be frustrated with my sample because it was limited to only one small region of one state in India. This is a difference in obligations, in what different disciplines feel comfortable reporting. I think it is possible for both of our studies to reveal interesting data given our methods. However, neither is the objective truth on the ground, collected as it was with different teams, methods, and assumptions. I call attention to research design here to emphasize that sciences dealing with human responses must pay special attention to the ways that research interlocutors construct facts than in a way that, say, physicists measuring neutrinos are not often asked to attend, even when national and legal discourse attempt to make them uniform or legible.

Divorced from billions of dollars of research and development, an international network of scientists, global capitalism, and farmers, development science maintains the experimental factish of the seed because it is the anti-political technological fix (Ferguson, 1994) through which development can occur. This discourse naturalizes India's agrarian distress. The problem is an ecological issue of pest attacks or pesticide use (Qaim, 2010), not a political question of clothing supply chains (Brooks, 2015), biotechnology infrastructure (Scoones, 2008), or colonial history (Beckert, 2014). When reduced to a single, scientifically observable benefit, yields, GM seeds allow the rest of the cotton supply chain to continue through this crisis without challenging the underlying inequalities of the cotton trade.

## Conclusion: Attending to the Factish in the Field

A re-reading of Latour's concept of constructionism allows us to see how facts are constructed and shaped while simultaneously showing how they are de-politicized to mask intention on the part of the author and avoid questioning researchers' methods. Why would a yield be the most important thing to measure anyway? The discussion around the success and failure of Indian cotton has been framed in this way since GM cotton was legalized in 2002. This pushes other concerns, including risk or public fears expressed by non-experts and framed outside of agronomy, to the side (Herring, 2015).

STS approaches critically examine the methods and assumptions of laboratory and field research. Like the authors discussed in this essay, I have described seeds as autonomous and yield-creating beings to make arguments about Indian cotton agriculture in my own work. It is not my intention to criticize the work of these other scholars but to draw attention to the ways in which all of us use models and create factishes that mask how this data is co-created. Anthropologist Paul Richards (1993), for example, is particularly suspicious of the field trials in which agricultural technology like GM seeds are tested, as these eliminate the variables of farm life and mask the improvisations that define farmwork in practice. From this perspective, it is not GM seeds but the collective work of farmers, landscapes, and measuring scientists who create yields and decide the productivity of a given seed. Agricultural and development models regarding GM seeds are useful and legible to scientists and policymakers as these generalizations can describe abstractions and amalgamations of farmers and seeds. The STS approach in this essay is a critique of the ways in which yields are divorced from farmers and fields in agricultural development discourse, and is not necessarily conducive to directing agricultural or economic policy. At least, I would ask that such policies pay far more attention to social variability and consider the multitude of factors beyond yields that reflect socioeconomic uplifting in areas targeted for agricultural development. Models that present seeds and yields as a fact of nature rather than a socially embedded and contingent factor are not equipped to address underlying rural precarity linked simultaneously to generational poverty brought on by colonialism, contemporary trade inequality, unequal access to irrigation infrastructure, and rural aspirations to land stewardship (Gupta, 2017; Gutierrez et al., 2015; Vasavi, 2012).

While I contest that seed models describe an independent and objective reality, I agree that the combined social work of farmers, seed breeders, agricultural scientists, policymakers, and other stakeholders help to make these yields a shared reality. In the first pages of An Inquiry into Modes of Existence, Latour (2013) notes that climate scientists are beginning to think of themselves as members of institutions with particular ways of evaluating evidence and making claims. Yet his recent work (Vrieze, 2017), and STS in a broader sense argues that this is an opportunity for deeper understanding, not a rejection of inquiry. In his *Compositionist Manifesto*, Latour finds that both proponents and skeptics of climate change cling to modernist scientific reasoning, arguing "if [climate science] is slowly composed, it cannot be true," said the skeptics; "if we reveal how it is composed," said the proponents, "it will be discussed, thus disputable, thus it cannot be true either!" (Latour, 2010a: 478). Both GM seed proponents and skeptics who research the seeds' impacts in the field buy into a similar factish, that seeds are autonomous beings and that crop yields can be measured objectively. By recognizing this experimental factish, as well as the promise and theoretical factishes that undergird it, we can begin to make sense of different stakeholders' reports on the triumphs and failures of GM crops, how they are collectively composed, and what obligations and requirements that process demands.

My assistant's initial objection, that the data would not exist without my collecting it, turns out to be exactly correct when viewed outside the parochial ecology of practices in my discipline of anthropology and my constructed experimental factish of the GM seed. All seeds and yields are born of wildly different environmental circumstances and entangled with different kinds of actors. That factish persists in my own work and in that of other social sciences for the same reason that factishes persist in biology or physics. They are useful abstractions that provide helpful generalizations, they are easily taught and practiced within the current institutions where we work, they are fundable and studyable within the confines of our disciplines, they allow us to remove ourselves from the laboratory and thus give our phenomena their own independent lives, and they require no extra theoretical work in the realm of the possible. But if any researchers can cope with compositionism and think beyond experimental or theoretical factishes, qualitative empirical social scientists should welcome the opportunity. My data cannot exist without my interactions with the farmers, but the farmer's fields, cotton, seeds, income, happiness, ecological management, and all of the hundreds of factors that have led to the process wherein seeds become plants are anything but external to the fields and farmers who grow them. By paying better attention to their interconnectedness, we may have a better chance at documenting the composed reality, not as it exists to be discovered and written on my clipboard, but as seed, farmer, and social scientist create it.

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## Notes

1 Bt refers to *Bacillus thuringiensis*, a naturally occurring soil bacterium containing Cry genes that produce a class of toxins poisonous to certain insects, most notably the order *Lepidoptera*, which contains major agricultural pests. Used as a spray pesticide for decades by American farmers, six different Cry genes have now been inserted into GM cotton in various combinations, allowing the plant to produce its own insecticide.

# **Strategic Research as a Mode of Academic Engagement:** Assembling Smart Energy Futures for Finland

*Mikko Jalas*

*Aalto University School of Arts, Design and Architecture, Finland/ mikko.jalas@aalto.fi*

*Mikko Rask*

*Consumer Society Research Centre, University of Helsinki, Finland*

*Tatu Marttila*

*Aalto University School of Arts, Design and Architecture, Finland*

*Tero Ahonen*

*Lappeenranta University of Technology, Finland*

## Abstract

Strategic research indicates a problem- and future-oriented, collaborative process of knowledge creation. Analyzing a Finnish research project, Smart Energy Transition, and a related Delphi survey, we conceptualize strategic research as visioneering and as translations of technologies, time frames and narratives into a relational actor network. We ask 1) How does strategic research condition and contribute to academic practices of visioneering, 2) What are the available means to problematize futures and create intressement in a Delphi survey, and 3) How do academics carrying out strategic research align themselves as part of actor networks? We find that strategic research brings forward and operationalizes new practices in the boundaries between science, business and policy. In our case, the notion of disruption was used to problematize futures. Moreover, plural time frames of short-term changes in actor networks and long-term speculative visions supported intressement. Alignment of academic actors in the project hinged on several issues including research methodology, specific academic backgrounds and expertise, public energy discourses, and national and industry interests.

**Keywords:** smart energy, disruption, visioneering, strategic research

## Introduction

'Smart grids' and 'smart energy' have become prominent labels for an ongoing technological change in energy sources, distribution systems, business logics, and demand (Ferrari and Lösch, 2017). Visions of a smarter energy production system include ideas on how to tackle global environmental problems while at the same time creating pathways for new cleantech industries, new jobs, and sustainable energy production (Leipprand et al., 2017). Yet, key technologies, their diffusion and integration with existing systems and the local contexts, contain significant uncertainties. Visions of smart energy are thus representations of anticipated and desired, yet highly uncertain and debated, futures (Ferrari and Lösch, 2017; Ballo, 2015; Engels and Münch, 2015; Butler et al., 2015).

While futures research and scenarios have been identified as particular forms of creating expectations and demand for new technologies and securing resources for further development of the technology (Bell, 2011; Geels and Smit, 2000; Borup et al., 2006), the active work of making visions and the unfolding of their impacts has received less attention. In this paper we follow a track identified by Ferrari and Lösch (2017) and focus on visioneering and 'visions as socio-epistemic practice'. We conceptualize such practices with the help of actor network theory and the notion of translation (Callon 1986a, 1986b; Latour 1993). At their core, actor networks are composed of human and non-human actors, scientific facts, engineering achievements, and social arrangements, each of which have identities and properties that have been adjusted to fit each other. Actor worlds come together via translations of existing entities into specific networks by the selective and purposeful interpretation of their key properties (Callon, 1986a, 1986b).

Visions as socio-epistemic practice strongly implicate a political and practical involvement of academics and blurring boundaries between science and society. Addressing such conditions, science and technology studies have highlighted the multiple ways in which academics and the institutions of science are intertwined with the surrounding society (e.g. Jasanoff, 2015, 2009; Nowotny et al., 2001). The thesis of entrepreneurial science (Eztkowitz, 2011) emphasizes the interaction of academics and the private sector in commodifying knowledge. Yet, the increased emphasis on impactful science also calls for further societal contributions. A broad range of academic work related to, for example, energy futures can be conceptualized as scientific policy advice (SPA), which is characterized by field-specific expert knowledge (Kropp and Wagner, 2010) and transdisciplinary pragmatic approaches to problem solutions (Leipprand et al., 2017). To spur such work, national research policy agencies have introduced specific funding schemes and criteria that reflect a research paradigm of future-oriented, challenge-driven *strategic research* (Rip, 2002, 2004; Aarrevaara and Dobson, 2016), which is also the institutional context of our study.

Science and technology studies have furthermore called for attention to modes of engagement and ongoing boundary work between science and the users of scientific knowledge (Lam, 2010; Möllers, 2017). Researchers should conform to a T-shaped identity of being both generalist and specialists (Rip, 2004). They also need to become the double servants of politics: First, they are expected to contribute to political processes by providing insights into the challenges ahead and visionary ideas about them, and second, to help decision makers to better address such challenges. Overall, the tenets of strategic research call for ongoing boundary work between science and politics or business (Lam 2010, Möllers 2017). Academics in strategic research not only tailor their knowledge into particular social concerns and thereby bridge between the conceptual domains of basic and applied research (Calvert, 2006; Möllers, 2017), but also actively construct demand for their knowledge and make themselves useful in the given political and practical contexts (Latour, 1993; Calvert, 2006; Hoppe, 2015).

We contribute to the discussions on visions as practice and strategic research by drawing attention to the ongoing tailoring and adjustment of the research activities vis-à-vis social expectations. More specifically, we take a Delphi survey as a particular research operation and trace how the survey questions reflect the processes of tailoring and pragmatic interests around the survey. The empirical material stems from a large research project called Smart Energy Transition (SET). The project was funded by a strategic research program of the Academy of Finland, premised on producing useful knowledge for societal purposes, and designed to use futures study methods in a constructive manner. Drawing on data including the funding application, project-internal position papers, participant observation, presentations, and interview data, we provide a close-range account of attempts to problematize energy systems, interest actors, and create a politicized space of possibilities in relation to smart energy technology. Specifically, we ask 1) How does strategic research condition and contribute to academic practices of visioneering? 2) What are the available means to problematize futures and create interessement in a Delphi survey? and 3) How do academics carrying out strategic research align themselves as part of actor networks?

We also aim at a pragmatic contribution. By following up how time scales and uncertainties were constructed and negotiated in the empirical case, we want to highlight the questions of closure and convergence in visioneering. Strategic research is premised on grand social challenges that call for concerted action. Yet the involvement of researchers in policy processes should thrive on transparency and openness regarding the means, paths, and potential actors (Leipprand et al., 2015). We address these issues in respect to existing concerns relating to the Delphi technique (Riikonen and Tapio, 2009), as well as addressing them on the broader level of strategic research.

The paper is organized as follows. We begin by elaborating on the concept of strategic research and how it encourages a close interaction among academics, politicians, and other societal stakeholders. We then briefly introduce the Delphi survey as a futures research method and the data we draw on, and proceed to focus on the SET research proposal, the ways to meet the request for politicized co-creation of research, the resulting actor network and the problematization of energy futures. Thereafter we follow more closely the technical elements of the network and process of drafting the Delphi survey questions and the technology portfolio. In the discussion section we return to the notion of strategic research and argue that it can be understood as an active way of constructing possible futures.

## Strategic research as translation

Rip (2002, 2004) dates the rise of *strategic research* to the 1970's and claims that such research blends aspects of 'basic' and 'applied' research into a new concept which reflects a practice of scientific inquiry combined with social engagement. At least since then, and voluminous through institutions such as EU Framework programs, problem- and solution-oriented research has proliferated. A brief look at our case study also highlights the logic. In the case of Finland, the Strategic Research Council (SRC) at the Academy of Finland was founded in 2014. The SRC aims to provide the scientific community with an opportunity to produce scientific information for government policy and decision-making. More specifically, the goal is to engage the end-users of research knowledge as early as possible and through this early engagement have the research needs of the end-users considered by the research teams. The logic of the funding instrument rests on co-creation or co-design on the one hand and the shared goals and practices of interaction on the other (Aarrevaara, 2015; Aarrevaara and Dobson, 2016).

The practice of social engagement and co-creation can be understood in different ways. Studying the scientific policy advice related to German Energiwende, Leipprand et al. (2017) claim that academics engage with advocacy coalitions and with the narratives they use in order to promote political goals. Supplementing politics, scientific work and the facts derived from it are used to pinpoint problems, potential actors, means–ends chains, and potential policy pathways. Controversies and gaps between opposing advocacy coalitions can be (and have been in the German case) mediated by providing knowledge that is normative but transparent. Being located close to policy making, researchers may become the "cartographers of policy pathways" (Edenhofer and Kowarsch, 2015; Leipprand et al., 2017). Yet, we suggest that the framework of scientific policy advice delivers a rather linear view on academic futures creation which does not fully take into consideration how researchers are embedded in the broader society that provides them with resources and commissions them to attempt translations and carry out practices of visioneering.

Visions as practice can alternatively be understood as attempts to translate existing entities into a network with a joint effect of constructing viable socio-technical arrangements. Ferrari and Lösch (2017, 79) suggest that socio-epistemic practices of visioneering can: "produce and designate spaces of possibility," "normatively translate the use of the spaces of possibility into an urgent need for the current society," and ultimately also "result in practical changes in the socio-technical arrangements and constellations they address." Visioneering hence contributes particularly to the aspects of problematization and interessement that Callon (1986b) identifies as the early moments of translations.

Sociology of translation underscores the active and open-ended nature of futures making. Callon (1986a, 1986b) and Latour (1993) describe technology development as the deliberate building of actor networks through which some actors can become prominent "spokespersons." Such actors seek to assemble actor worlds and enlist the needed social and technical components of envisioned future technologies by defining what and who is needed and how each actor should participate in the scheme. If the translation is successful, actors are mobilized and aligned, and action results (Freeman 2017). With this vocabulary, it becomes apparent that each element—be it organization, social actor, or a technical component—may have an interest in future energy solutions and a need to be represented in the actor network. Strategic research as an engaged form of collaborating with end users of research, hence can be viewed as attempts to assemble actor networks, represent entities and speak-for aligned interests.

Interests are suggested and represented through simplifications that contain the essential role of each actor for a particular actor world. The castings that are suggested and formulated in a responsive manner by spokespersons may however be challenged. Callon highlights that simplifications, which are needed to assemble the actor world, contain the seeds of controversy as they are but partial images of actors, as if they only existed in order for the project to unfold. Indeed, Latour (1993, 65) insists that translations are by definition misunderstandings that serve to align the diverging interests of the parties involved. It follows that not all translations succeed and dissidence will follow (Callon, 1986b). Moreover, if the work of translating actors and assembling interesting futures is premised on productive misunderstandings, the request for transparency around scientific policy advice becomes conceptually difficult: each of the viewpoints of actors are partial, science-actors are no different and ultimately the viewpoints and workings of actors cannot be transparent to others but merely translated.

For these very reasons, the notion of translation can be also used to conceptualize the interface between science and society. Freeman (2017) suggests that research projects at the same time realize translations and are realized by them. This is to argue that the work of researchers may be organized by the same principles (of administration and governance) that they are to study (Freeman, 2017) and that researchers look for demand for their research and move horizontally between the laboratory and the social context of the produced knowledge (Latour, 1993). In our empirical case, it is to argue that insofar as the researchers are successful in participating and speaking an entity such as smart energy transition (for which no shared understanding exists), they also constitute (a need to study) smart energy transition. It is this dynamic that we seek to capture with our first research question: How does strategic research condition and contribute to academic practices of visioneering?

The notion of tailoring (Calvert, 2006; Möllers, 2017) highlights the problematic aspects of visioneering and the boundary work that is performed between science actors and the users of knowledge. It denotes, firstly, efforts by researchers to tailor forward, i.e. point out how their results can be applied and what the relevance of their work is. In our empirical study, we have operationalized the question of forward tailoring in asking how the background of researchers affected the SET project proposal and the Delphi survey questions. On the other hand, reverse tailoring, Möllers (2017) suggests, involves attempts to redefine the social problems as formulated by funders to better fit the researchers. Turning this into an empirical question we report on how the SRC and the specificities of the call, the contemporary political power balance of Finland, affected the research proposal and the Delphi survey as a particular operation.

A priori, we do not think that strategic research necessarily produces an excessive need to tailor or particularly problematic identities for researchers. It calls for extending roles or switching them

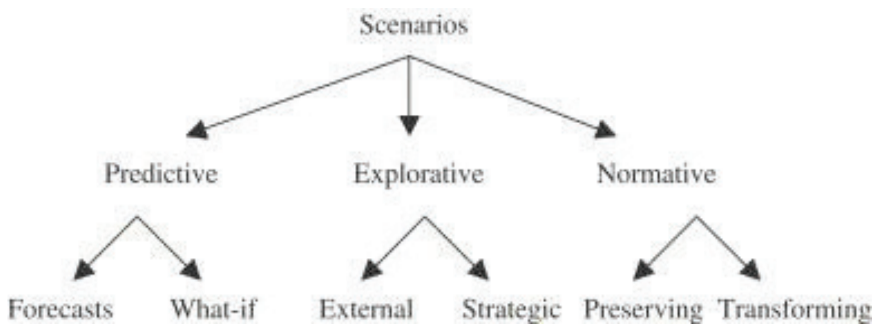


**Figure 1.** Scenario typology (Börjeson et al., 2006)

towards entrepreneurial scientists, but as Lam (2010) reports, such roles are increasingly common. Indeed, existing research on the SRC also indicates interesting results regarding the changing role of researchers (Aarrevaara, 2015; Aarrevaara and Dobson, 2016). Their central aim in the projects is to pursue high-quality research, but alongside this, a picture emerges of researchers actively functioning as a type of facilitator within the project. Such activities are clearly linked to their will to influence societal matters and processes. Rather than focusing only on the scientific work, these researchers put time and effort into building cooperation systems, not only between researchers and stakeholder partners, but also between the different stakeholder partners. Such triangle-like cooperation building is seen to benefit the issue to a degree that makes such actions worth the effort. This finding is particularly interesting as it surpasses the idea that researchers need external mediators between the scientific world and the rest of society in order to get their message across.

## Delphi-survey as a tool for scenario-building, problematization and interessement

Before moving to our empirical analysis on the translation efforts around smart energy technology, we briefly introduce the Delphi survey as a technique and a key ingredient of these efforts. The Delphi survey as a technique was developed in the 1960's to conduct anonymized and iterative polling of expert opinion (Linstone and Turoff, 2010; Gordon, 2000). Diverting from the aim of producing reliable predictions, Turoff (1970, see also Hasson et al., 2000) has developed a 'policy Delphi' and suggested that Delphi processes can be geared to explore underlying assumptions leading to different judgments and to educate respondents on a topic. Delphi surveys are frequently used to support scenario work (Nowack et al., 2011) and useful basic distinctions between Delphi methods can be derived by considering differences in scenario types. An established way to classify scenarios is to distinguish between scenarios of probable, possible, and preferable futures (Börjeson et al., 2006; Masini, 1994). Scenarios of possible and preferable futures imply an increasing scope of action as futures are not viewed as being determined but as being actively made. Indeed Börjeson and colleagues (2006) suggest that the purpose of scenario building might be used as a basis for a typology (Figure 1).

Predictive scenarios spotlight particular technologies (Geels and Smit, 2000) and may seek to address the conditions of their further development in the form of a what-if analysis. In the field of energy studies the 'grid parity of photovoltaics' exemplifies predictive deterministic scenarios. Normative scenarios are more outspoken in terms of political goals: They are built on a desired end-state and look for the means to achieve this state. Backcasting as a particular method can be viewed as a transformative scenario that is built on a problematic view of current trends and a need to change the parameters and structures of the system in which futures unfold (Robinsson, 1982). An example of this type of scenario setting would be processes that fix and aim at, for example, a given share of renewable energy production. Exploratory scenarios, according to Börjeson and colleagues (2006), seek to answer the question

'What can happen?' referring to either external factors or strategic actions in particular futures. Specifically, in comparison to the what-if type of scenarios, they state that "explorative scenarios resemble what-if scenarios, but the explorative scenarios are elaborated with a long time-horizon to explicitly allow for structural, and hence more profound, changes" (Börjeson et al., 2006, 728). Exploratory scenarios of, for example, smart energy technology may thus play with long enough time periods in order to evoke uncertainty and complexity and yet leave the desired end-state or outcome unarticulated. In general, Delphi studies need to strike a balance between time scales that either allow or limit exploration of new emerging solutions (Börjeson et al., 2006; see also Ferrari and Lösch, 2017).

## Data and methods

The case we use consists of three layers: the call by the SRC, the research proposal by the SET consortium and the Delphi survey planned by researchers in the project. In terms of the level of the SRC, we rely on previous published work (Aarrevaara 2016; Aarrevaara and Dobson, 2016). Our analysis covers a period from initial drafting of the project plan "Smart Energy Transition: Realizing its potential for sustainable growth for Finland's second

**Table 1.** Key phases of the analyzed futures work

| Phase | Available and used documents | The role of the documents |
|---|---|---|
| Assembling the consortium | Consortium memorandum 19.03.2015 (5 pages); Consortium memorandum 01.04.2015 (7 pages); A list of the intended members of the technology panel 22.04.2015 (Excel sheet) | Early ideas on what smart energy is, who could be in the consortium and the adjunct technology panel, and how technological disruption should be conceptualized |
| Submitting the proposal | Project application 29.4.2015 (19 pages) | First formal ideas about the Delphi survey, including a five-year time frame |
| Redefining the scope of the project after a positive funding decision | Position papers by six project partners (each 1–2 pages long) | The exchange of ideas amongst project partners regarding which technologies should be studied in the whole project |
| | Memorandum of a meeting on work package 1 (WP1), held on 7.1.2016 (4 pages) | The first meeting of the Delphi group; the memorandum presents the first listing of technologies for the Delphi survey |
| Planning the Delphi survey | WP1 Delphi interview guide, 15.1.2016 (3 pages) | Presents the first formulation of the intended questions for the Delphi survey |
| | Interview notes from first-round interviews (9), February 2016 (each with approx. 3 pages of text) | Documents 1) interviewees' understanding of the disruptive features of new energy technology, 2) suggested changes to the planned survey questions |
| | The Delphi questionnaire's technology descriptions, 20.3.2016 (1 page) | Introduces each selected technology with one sentence to be used in the survey. |
| | Survey questions and respondents' comments on the test run of the survey on the eDelphi platform 29.3.2017 (54 pages) | This presents the first demo version of the online survey and the responses of trial users |
| | The report on the first round results of the Delphi survey, 20.4.2017 (110 pages) | This presents the final survey questions as well responses and discussion of the questions |

century" (SET) in early 2015 to the roll-out of the Delphi survey questions in April 2016. [1]

The empirical material that we draw on mainly consists of internal project documents of the case project. As all the authors have themselves worked in the project, participated in several meetings, and exchanged emails with other project partners, this offers a more thorough background understanding of the case. Table 1 lists the key steps in the analyzed project, the documentation that has served as the empirical material, and the key insights or role the document has in the analysis.

Most of the above documents are management documents containing abbreviated text describing discussions in meetings or presenting plans and lists of items for upcoming work. They have mainly been written for project participants rather than for an external audience, with the major exception of the funding application. We have approached the text as a factual description of the choices made in the project, placing emphasis on how actors and technologies were brought into the realm of smart energy. The outcome of such work is a changing list of relevant elements. In addition, and in particular relating to the moments of problematization, we have analyzed the discursive strategies of the SET proposal text and metaphors of disruptions that were placed in the proposal and the Delphi survey questions.

In addition to drawing on the documents created and interviews made during the planning of the survey, we interviewed the key actors of the project in spring 2017 to verify our results. These interviews were conducted with the principle investigator of the SET project, the key academic content provider (who drafted the first version of the proposal), and the policy liaison officer of the project (who has a key role in facilitating the interaction between researchers, companies and the policy makers in the SET project).

## The consortium and grant application: Smart energy transition as a research proposal for strategic research

We have divided our analysis of the SET project into two parts. In this section, we focus on our first research question about the way strategic research configures visioneering. We account for the drafting of the SET proposal and for the way in which the content was tailored to fit both the involved researchers and the social context of the project. The next section dwells on the second research question and on the work that took place after the positive funding decision, highlighting the different views that existed inside the consortium, the adjustment of the work program and the Delphi survey as an element of visioneering.

The analysis of the empirical material is also informed by the notion of visions as practice. We hence analyze both the making of the proposal and the establishment of smart energy transition as a shared vision, and the operationalization of such vision and the interessement of an actor network through a Delphi survey with particular informants and questions posed to them.

### *The forming of the SET consortium in response to the SRC funding instrument*

Strategic research implies multidisciplinary and -sectoral work (Rip, 2002 and 2004). The SRC followed this principle by requiring the consortium consists of at least three research teams, which represent at least two different organizations (e.g., universities, research institutes, civil society organizations, or private companies). Moreover, the researchers needed to represent at least three different disciplines. Additionally, the candidates were informed that it was expected that at least two, preferably three, government ministries would be involved in the projects. This was in addition to stakeholders from the private sector and/or the civil society sector.

The SET consortium had little leeway or need to challenge these predications of strategic research. While the consortium drew on the established joint research efforts of the business school partner, the political science partner, and the environmental policy research partner, such a consortium was not regarded as competitive in the call. Rather, the initiators from these three units reached out for both expertise in energy and building technology and economics, and for an organization that represents users of knowledge. The final consortium included:

- a management studies department in a business school
- a political science unit
- a design department in an arts school
- an engineering department working particularly with solar and wind power production technology
- a building technology research unit
- an institution for economic research
- an environmental policy research unit
- a state-owned company for promoting energy efficiency
- the city administration of a mid-sized Finnish city.

The consortium members anticipated and inquired into other competing applications and sought to combine forces with other research institutions with an established position on energy-related research. These attempts at mergers between consortia were however not successful: According to he consortium leader, the consortium came out to be an "innovative but not obvious" collection of partners and sought a viable niche by rephrasing emerging energy technology as *major societal disruption*.

### *The drafting of the funding application and the problematization of energy futures*

In the first call of the SRC in 2015, the three main themes for strategic funding were (1) the utilization of disruptive technology and changing institutions, (2) a climate-neutral and resource-scarce society, and (3) equality and its promotion (Aarrevaara and Dobson, 2016). The SET project application was written for theme 1 of Disruptive Technologies and Changing Institutions. Overall, it built upon a view of global technology change disrupting Finnish energy systems. The first formal version of the research plan, which was used to assemble a further consortium, envisioned the following energy future:

> Breakthroughs in the development of smart grids, metering, power storage, power-to-gas, power-to-chemicals and the Internet of Things jointly represent a disruptive set of technologies influencing Finland's spearheads of growth: digitalization, cleantech and the bioeconomy. These smart energy solutions will cascade into new business ecosystems with unprecedented opportunities for cleantech development, but also leading to radical shifts in the role of producers, service providers and consumers. When combined with renewable energy cost reductions, this transition is disrupting the old rules of the energy system and shifting industry boundaries like the ICT revolution did. The IEA (2014) has estimated that the global energy transition creates a 50 000 billion dollar cumulative market in the next 20 years. The Smart Energy Transition (SET) project tackles the ongoing changes and demonstrates how Finnish industry can benefit from the emerging disruptive technologies around smart energy. (Research plan Smart Energy transition)

The consortium certainly stated rather boldly that it had insight into the forces that are going to affect Finnish actors in the future in a significant way and even cause disruptions in the energy systems. The notion of disruption, used by both the SRC call and the SET proposal, thus serves to evoke uncertainty and problematize energy futures. The text also enlists other fields of technology and actors, such as consumers, into the network. However, playing with the notion of disruption effectively undermines any direct predictions. Moreover, being uncertain about which areas and for which actors the ramifications of smart energy disruption might be most significant, the application serves as an explorative starting point. Finally, by inserting the notion of transition and by seeking to find effective ways for Finnish actors to cope with this disruption and even benefit from it, the plan takes a transformative view of the future, seeks to interest policy actors, and questions how to effectively steer social development towards a low-carbon energy system.

In the subsequent project meetings, the research group further crystallized the key logic to be placed in the application. The proposal claimed: international technology development will both push towards a change in the Finnish energy system and create business opportunities for Finnish companies in international markets; the process will create both winners and losers as existing resources and competences become redundant. The sheer force of international technology development is suggested to undermine any conservative strategies. Moreover, the consortium agreed to claim that, with proper policy tools, disruptive technologies can be taken into use and acted upon in a more concerted way, as the project name 'Smart Energy Transition' suggests.

The notion of disruption runs through the three levels of our empirical examination: the call, the proposal and the Delphi survey. Disruption was regarded to imply a particular time frame. Whereas Leipprand et al. (2017) suggest that longer time frames contribute to more proactive and change-oriented energy discourses, the SET proposal endorsed a short-term view. Quite explicitly, the development of the new Finnish actors in the energy field was regarded as interesting within a time scale of five years, whereas long-term predictions were regarded as difficult to make and uninteresting from this point of view. A retrospective interview with the principle investigator of the project revealed the logic for short termism. Insofar as disruption can be viewed as a rearrangement of existing actors and their interest, one can study and contribute to such change in the short term.

The plan included a dedicated work package (WP1) that was to study "the rate, direction and impacts of the technological transition" as well as "the possible directions, triggering factors, rates and impacts of ongoing disruption in smart energy technologies." Our participant observations indicate that such a 'techy' work package fit the engineering members of the consortium and was seen to both strike a balance with other work packages driven by social science and raise the credibility of the proposal. The work package was further split into the subtasks of conducting a Delphi survey to establish the rate and direction of technological change within a five-year time span, and a separate task, projecting the anticipated developments in digitalization, cleantech, and bioeconomy. In other words, the problematization occurred by suggesting that energy futures can be acted upon instead of a view of global developments to which Finnish actors simply need to adjust. Hence, the project plan aimed to organize processes in which multiple, distributed actors could fill in details about how the likely changes in the Finnish energy system could potentially unfold. Yet, by initiating a set of core technologies, the academics working in WP1 nevertheless acted as spokespersons for a particular network.

Tailoring as boundary work took place in respect to selecting a theme within the SRC call. Our ex-post interviews reveal that making disruption the mainstay of the proposal was regarded as a very risky strategy. Yet, the consortium stuck with theme 1 and the notion of disruption, as this was broadly viewed to fit the credentials of the consortium better than 'climate neutrality and resource scarcity', the alternative theme in the call. Tailoring took place also as the proposal was tuned politically. The writers of the application regarded the upcoming parliamentary elections and the pending success of an agrarian party as an added reason to put emphasis on aspects of biofuels. Hence, tailoring of the proposal and research interest was far more than lip service (cf. Calvert, 2006) but rather included a substantial realignment of the work program.

The technology focus of the application and notions such as *smart grid* and *intermittent power production* reflect a productivist technology discourse but also forward tailoring, i.e. the expertise areas of the consortium. It is obvious that the application was premised upon (and also created future demand for) such expertise (cf. Latour, 1993). However, while the consortium had extensive technical and business knowledge—particularly in the area of solar energy—the decision was to put the focus on a broader set of technologies related to renewable energy. This was to signal that the potential impacts of disruption, the actors implied, and the work of the SET project were to span existing industries and several sites in which energy is used: In addition to energy production technologies, the application included work on buildings and vehicles as sites in which energy can be produced, stored, and used in a distributed manner. Parallel to this, there was a more fundamental shift from the narrow areas of expertise of the consortium researchers towards studying the broader impacts of the disruption on less familiar terrains.

The SRC and the notion of strategic research pushed the SET application not only toward interdisciplinary work but to include non-academic actors. The initiators of the project hence enlisted practitioners and interest groups as carriers of interests by asking for Letters of Commitment. Such letters were particular devices for tailoring as they demonstrated the potential applicability and short-term relevance of the results. Interessement thus proceeded already at the point of drafting the proposal and prior to any 'strategic research'. The following actor categories were drawn into the domain of smart energy transition:

- equipment technology manufacturers
- energy companies
- measuring and sensor technology
- energy efficiency services
- consultants
- smart traffic.

## SET in motion: Crafting an energy disruption into a Delphi survey

The planning of the Delphi study was already started when drafting the application. Key technologies, such as new forms of intermittent power production by solar and wind sources, were mentioned in the application. However, much of the content of the survey remained open at the time of submitting the application. After a positive funding decision, the partners thus needed to reassemble visions of smart energy and relevant research foci. After establishing the first ideas about the content, the planning of the Delphi survey followed guidelines given in previous research (e.g., Gordon, 2000; Riikonen and Tapio, 2009). Accordingly, organizers need to select a few knowledgeable and willing respondents and create a background understanding of the issues through interviews. Thus, it was the SET project partners and the few interviewed external actors who had the opportunity to draw in technologies, trends, observations, or emerging knowledge pools to the energy vision created for the survey.

Both more need and leeway for reinterpretation of the execution of the survey appeared within the consortium. In particular, the time frame and the technology mix—the technologies that are suggested to cause the disruption and amplify its effects—needed to be redefined.

### *Turning from predictive to strategic Delphi*

While discussions during the phase of writing the SET proposal listed five-year, 15-year and 30-year spans, the final plan did not specify other time spans than a five-year technology outlook that was to be based on predictive technology forecasts. Reconsidering time scales from the point of view of strategic research, it however became evident that a longer study frame was also desired. The position papers from November 2015 suggested a study of the potential impacts running up to 2025, whereas a later project meeting (07.01.2016) suggested the following time horizons: 2020 for a technology outlook, 2030 for a policy-level futures study, and 2045 for a scientific outlook. In the Delphi interviews and the demo version of the survey, the project group responsible for the survey indeed trialed different time scales for different questions. However, as this appeared to create confusion, the time frame was fixed to run to 2030.

### *Fixing a technology portfolio*

The technology portfolio of the survey was another subject that was modified after the funding decision. We account for the changes in tables 2 and 3. In the first phase, the consortium leader requested a focus proposal from each participating research institution detailing the key energy production and storage technologies that should be studied and the other relevant technology areas. This process is documented in position papers by six participating research institutes (see table 2 for a summary). These position papers exhibited a wide range of issues, potential impacts, and areas, branches, and industries that seemed to be challenged by smart energy technology. Compared with the application document, they added weight on the dynamics of industrial restructuring and put less emphasis on digitalization and on the Internet of Things. Another change in orientation is the stronger presence of bioenergy that came through in the mentioning of alternative biofuels for cars, the availability and competing uses of forest biomass and the challenges associated with all energy production that is based on burning organic matter.

Soon after the position papers were written, WP1 assembled to plan the Delphi survey. Some technologies were considered to be too radical. For example, fusion energy was discussed as a possible item on the list of technologies, but

**Table 2.** Summary of the technology portfolios in the position papers written by individual academic partner organizations (6)

| Which renewable energy production and storage technologies should be analyzed? | What other key technologies should be included? |
|---|---|
| Production technology<br>• Photo voltaics (PV)<br>• Wind<br>• Geothermal<br>• Hydro<br>• Solar thermal<br>• Heat pumps<br>• Bioenergy from agri- and silviculture, biogas<br>• Old renewables (water, wood)<br>• Tidal<br>• Heat pumps<br>• Heat storage in district heat networks for surplus wind power<br>• The integration of energy production from different low-carbon, renewable sources<br><br>Storage technology:<br>• Hydrogen<br>• Water/networks<br>• Electric vehicles<br>• Batteries<br>• Power-to-gas technology, power-to-chemicals technology[2]<br>• Ground and water heat storage | • Net-zero energy buildings<br>• All new energy-efficient construction technologies, HVAC and automation systems, and building-scale heat and power systems<br>• LED lighting and smart appliances<br>• Automation and control technologies<br>• Measurement technologies, data mining, data analytics, anomaly detection,<br>• Smart metering, power transmission and grid technology, smart grid, demand response<br>• Digitalization: the Internet of Things<br>• Functional energy chains e.g. from electricity to chemistry (material synthesis), electricity to food (food production) and electricity to gas<br>• Existing gas-operated systems & the utilization of existing infrastructure<br>• Transport: from oil to alternative propulsion systems (electric and advanced biofuels etc.)<br>• Wild cards? Including CCS, nuclear fusion<br>• Process industries, especially steel, other metals and concrete<br>• Green chemicals<br>• Competing uses for biomass (biochemistry) |

group members expressed anxiety about this issue. It would follow that other novelties such as biomass from algae production would need to be included. The time span and uncertainty about developments were not the only difficult aspects of scoping the technology portfolio: The content resonated between thinking about their significance in Finland and for domestic operations, and their significance in the export markets of Finnish companies. As no existing or emerging actors and interests in these to-be-excluded technologies were identified, translation did not occur and they were considered as empty promises that might create uncertainty but could not be effectively used to arrange actor networks. In a later phase, carbon capture and storage, and a novel concept of a 'power-to-food' energy chain, were also excluded as no existing actors or sites of relevant development could be identified. On the other hand, the portfolio came to include technologies such as large-scale solar heat and wave power since they had local technology actors in Finland (although apparent potential in Finland is less obvious).

The resulting iteration of the selection of technologies was presented in the Delphi interview guide, which was used to engage experts in the content of the survey. The interviews included six project partners, some of whom had been involved in writing the position papers, and four external practitioners in business and policy. Interviews affected the survey design in several ways: Energy demand and technologies of demand reduction gained prominence. This applied to the energy efficiency of buildings but also comfort expectations were mentioned.[3] The tendency of future studies to focus on energy production technologies (Zehner, 2014), which was clear in the scoping papers and the initial work plan of WP1, was thus partly resolved by the interview round conducted amongst diverse project partners in which both members of academia and practitioners raised concern about the overtly production-oriented focus of the intended study.

**Table 3.** Questions about disruptive energy technologies in the SET Delphi survey. Italics in the list refer to added technologies

*What is the role of the following technologies for the Finnish energy system in 2030? [options:* not significant; a promising alternative; a commercialized solution; a solution which has replaced key parts of the existing system*]*
*What is the role of the following technologies for Finnish exports in 2030? [options:* scant opportunities; some opportunities; major opportunities*]*
*How and where will the following technologies be taken into use by 2030? [options:* as off-grid solutions; as part of local distribution networks; as integral parts of the national systems; used during peak-loads*]*

- PV
- *Solar heat*
- *Wind energy*
- *Wave energy*
- Li-ion battery storage
- Other chemical storage of power
- Fuel cells
- Automated systems of demand response
- *District-level heat storage*
- *Geothermal heat*
- Heat pumps
- Carbon capture and utilization (CCU)
- *New ways of utilizing forest biomass in energy production*
- *Utilizing waste streams in energy production*

Moreover, as the interviewees had criticized Finland for a tendency to stick to forest biomass as the mainstay of new energy systems, they also politicized the survey by adding a question about the future of biomass in the case where burning was ruled out. Finally, the interviews also caused the above-mentioned shift in timescales. Instead of working with the five-year frame, the final technology portfolio was connected to the year 2030 (table 4).

Compared with the project plan, and in line with the position papers written by partners, the final version reflects an increasing need to account for storage technologies and other facilitating solutions for the increasing share of intermittent power production. It also builds on an actor perspective: Additions such as wave energy and geothermal energy were added according to ongoing technology development and automated demand response was added according to heightened interest amongst policy makers. On the other hand, biomass refers to the old established actors and interests that were refashioned into the new configurations of Finnish energy systems. These changes are partly effects of the SET researchers having been increasingly exposed to the topic in the early phase of the project. Hence the development of the survey reflects the basic premises of strategic research in which multiple stakeholders co-construct futures.

### *Using a Delphi survey to create interests and coordinate actors*

The choice to conduct a strategic Delphi resonated with Turoff's (1970) ideas on a policy Delphi: The survey was viewed as an opportunity to draw actors in, make translations, and suggest particular roles in new actor networks. This decision had strong impacts on the Delphi study. Rather than focusing on international technology development, it turned to focus on the ramifications of smart technologies in Finland. It also followed that the Delphi panel would be held in Finnish, consist of Finnish experts, and also include policy makers. Even the notion of expertise was changed. Instead of trying to poll the rate and direction of technological development amongst technology experts and speak to policy in the name of such expertise, the survey sought to consider the interests of potentially impacted Finnish actors.[4] Interessement did not however only take the form of invitations to partake in the survey, but also in the way that the questions were formulated. The categorization of potentially impacted domestic actors in the final survey was as follows:

- home owners
- the owners and operators of public buildings
- energy companies
- service business
- ICT and data management
- energy-intensive industries
- the transport sector
- agriculture.

The survey was also broadened towards further implications of the diffusion of novel energy technologies. It came to include questions on who is likely to suffer from this change. Potential "crises" or highly ambiguous futures were constructed against major CO2-emitting processes by asking whether they will perish or remain as "necessary evils." Thereby actors such as coal-power producers, peat producers, and waste incinerators were also enlisted as relevant entities.

### *Disruptive narratives and prompts in the survey*

The SET project and the planned Delphi survey were premised on an image of the disruptive global technology forces that are affecting the Finnish energy system and its actors in a fundamental but unpredictable way. Listing energy technologies such as carbon capture and utilization created increasing uncertainty. Yet, in order to politicize the disruption, the survey was aimed at creating visions of potential strategic action. While the selected technology portfolio, the time frame, and the list of potential interest groups already suggest a particular actor network, future visions also depend on a narrative of problems, opportunities, and threats (Paschen and Ison, 2014; Leipprand et al., 2017). As the final part of our analysis, we thus briefly turn to aspects of narrating energy disruption in Finland.

The planners of the survey had used the notion of a 'second wave of electrification', which referred to "the electrification of energy systems as many renewable energy technologies relate to power production and many energy-efficiency technologies, including heat pumps and electric vehicles, require electric power as an energy form." In addition to this, the Delphi interviews brought about new narrative structures of energy disruption. New representations of the key outcomes of the disruption derived from the interviews and included 'post-fire era', a 'capacity market (as in telecom)', the 'decentralization of energy systems', the 'active role of prosumers', and a 'window of opportunity for system integration'. These open formulations were used in the Delphi questions in order to sensitize respondents to the magnitude and type of potential changes and the potential roles actors might assume.

## Discussion

The role of expectations and visions for technology development and socio-technical changes has been subject to wide academic interests (Borup et al., 2006). Following STS scholars such as Callon (1986a, 1986b) and Ferrari and Lösch (2017) we have suggested studying the acts and practices of visioneering. The analyses sought to shed light on how miniscule elements of visioneering such as Delphi survey questions reflect broader structures such as funding instruments.

Our first research question concerning how strategic research conditions and contributes to academic practices of visioneering appears to hinge on the notion of disruption. Disruption served to establish an explorative and constructive agenda for visioneering. The notion of disruption that the SRC used in the call, and that the SET project used in the proposal, effectively dispersed interest across academic silos. While disruption in the SET project was perceived to have a technical core, namely increased PV and wind power production, potential ramifications were proposed to be scattered across different technologies, industry sectors, and social actors. Moreover, the notion introduced uncertainties in who might be impacted upon and who should concerned and aim to develop strategic responses to new energy technology. To follow such a path of visioneering, practices may be aimed at translating existing, emerging and even missing entities into actor networks. Such bridging is clearly different from either predictive or transformative Delphi approaches. For STS scholars the implication is that strategic research may neither be traditional in the sense of predicting likely developments nor thoroughly political as providing means for predetermined ends, but rather speculative and explorative.

Our second question concerned the use of a Delphi survey as a tool for problematization and interessement. The Delphi planning began with a view of the major technological disruption brought about by intermittent power production and the need to store and use power in new applications during peak production. However, the heterogeneity of the consortium allowed for plural views of future development. The Delphi interviews proved critical in altering the content of the survey from its technology focus to the broader aims. The analysis of the SET project resonates with Zehner's (2014) claim that energy futures are often based on production technologies rather than addressing radically lowered energy demand. In this sense, the notion of disruption was not in itself enough to divert the path of the survey planning, but the interviews with the consortium members and external partners provided a reflexive space for thinking through the potential impacts of smart energy technology.

Can expert panels and Delphi methods be expected to deliver radically new or innovative futures? To begin with, translations need to build on existing entities and seek to bring them into new relations. Destabilizing prompts, such as a post-fire era, were used in the SET project to suggest impact mechanisms and outcomes that could interest and even mobilize actors. Key challenges relate to balancing between radical, disruptive notions of futures and capturing the interests of practitioners and making disruptions actionable. The notion of translation and actor network theory in general provide some hints. The enrolments of existing entities and the translation that occurs between networks imply that futures are made of existing elements, altered relations and interest-generating misunderstandings (Latour, 1993). Moreover, our results highlight that time scales are important aspects of problematization and interessement. Whilst Leipprand et al. (2017) view longer time scales as important for putting forward strategic analysis, Ferrari and Lösch (2017) suggest time scales need to be plural: They need to include the established "old" elements, the emerging elements, and the missing elements. While the missing elements do not exist, they can be represented by laboratories and scientific formula (Callon 1986a), as well as field experiments (Ferrari and Lösch, 2017). Yet, based on our findings, multiple time frames are difficult to manage in a Delphi environment.

Our third question concerns the alignment of researchers as part of actor networks. We contend that the proliferation of strategic research as an academic identity and occupation requires better understanding of such alignment. One interpretation is that strategic research is being made on order for political purposes. Insofar as such research is transparent and the contributors are plural, such work may contribute to conductive policy processes (Leipprand et al., 2017). Another interpretation is that academic actors retain autonomy and use their existing knowledge resources, skills, and backgrounds to continue research efforts in their selected paths, engage in tailoring and push knowledge into the hands of users (Calvert, 2006). A third, more novel idea about the relationship between science and policy is to think along the lines of strategic research, the facilitation of knowledge making by heterogeneous actors and in terms of actor networks and translation. In this case, the roles of spokespersons and acts of translation constitute a new academic practice. This might be a creative practice, but it may also hide the politics of academic work. In the case of the SET project, staying rather firmly in the area of strategic Delphi research helped researchers to dodge normative questions about the desired end results and also the question of opting out from particular opportunities (cf. Felt, 2015). Hence, competing discourses, such as bioenergy and increased electrification, were present in the survey.

We have also claimed that SET researchers engaged in a different type of tailoring. This was evident in the planning of the project as well as in the execution of the work. The research proposal was drafted based on the resources and existing knowledge of the consortium, but also in anticipation of evaluators, the pending political climate, and other competing proposals, as well as on forming new alliances with other social actors. These results suggest that SRC funding has been able to create room for (or forced) researchers to create new combinations of knowledge and expand their activity towards participating in social change. For us, the gradual evolution of the research agenda represents a safeguard against academics being subordinated by political needs, even when they themselves are framing and then being faced with questions such as “How can Finland best benefit from smart energy disruption”.

The question of alignment between researchers and pragmatic interests can be viewed as a layered phenomenon. On the most abstract level, strategic research calls for impacts such as contributions in the future success of a nation and expects researchers accordingly to pick and engage with grand societal challenges. On another level, the project consortium negotiated a fit between the resources, abilities, and academic histories in the consortium and the recognized challenges. Finally, the research methods indicate different forms of societal engagement and lead to more or less inclusive and responsive work processes. Hence, in our case the Delphi survey questions as the one outcome in the project were ordered and structured through these different levels: the SRC, SET and the Delphi survey as a futures study technique. In the current case, the middle level and the academic community of the SET project has proven particularly relevant.

## Conclusions

Energy futures are profoundly open, whilst being rooted in current technology development and social structures. The notions of translations, visioneering, strategic scenarios and strategic Delphi thrive from this position: Futures are actively made by combining existing elements and emerging elements into visions that are able to capture, create interest and even mobilize implicated elements and participants.

In this paper, we have suggested that academics addressing issues such as smart energy engage in visioneering. This notion highlights the active practices of translating existing entities into new networks. Such work is increasingly prominent as funding organizations push academics to engage in policy making and business, and to make contributions to solving grand social challenges under the rubric of strategic research. Our interests initially lay in the way policy and business actors influence academics, and the way that academics strive for sovereignty. However, the case also witnessed the notion of strategic research as a process of co-alignment through which new futures, new identities and new research settings are being crafted. Critical questions, however, also arise. The previous knowledge base, forms of expertise, and social networks certainly influence the perceived space of possibilities.

On a pragmatic level the overall objective of this paper has been to try to better understand closure and convergence in visioneering. Strategic visions derive power from convergence: They amplify particular possibilities and exclude others. The notion of disruption, which is in frequent use in strategic research, proved to open up space for possibilities. Yet closure, convergence, and alignment with existing interests are parts of an evident and needed process, and they also concern academics. Whilst such processes can be seen to take place on different levels, our results highlight the importance of both the collaboration inside the multidisciplinary consortium and the methodological choices (such as Delphi surveys and expert interviews). In our case they affected both the time frame and technology options of perceived smart energy futures.

Beyond dealing with issues of managing closure and convergence, this paper has also attempted to contribute to the academic practice of strategic research. Insofar as academics are explicitly called upon to engage in futures making and in the quest for recipes for success, both self-reflection and critical examination of researchers’ agendas appear to us to be fundamental elements of strategic research.

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## Notes:

1 www.smartenergytransition.fi

2 Later power-to-x came to be used in all conversion processes in which the high supply of intermittent power production can be converted into other forms of energy (heat) and energy carriers (e.g., hydrogen and synthetic methane), which can then be further used in novel production processes reaching all the way to power-to-food which refers to using methane in protein production with anaerobic bacteria.

3 These topics did not become included as "technologies." Energy efficiency was however introduced in other parts of the Delphi survey.

4 Invitations were sent by personal email to about 250 email addresses.

# **Profiles of Malaria Research in Portugal:** Organizing, Doing and Thinking in Science Under Capitalism

*Ana Ferreira*

*Centro Interdisciplinar de Ciências Sociais (CICS.NOVA), Faculdade de Ciências Sociais e Humanas da Universidade NOVA de Lisboa (NOVA FCSH)[1] / aferreira@fcsh.unl.pt*

*Ana Lúcia Teixeira*

*Centro Interdisciplinar de Ciências Sociais (CICS.NOVA), Faculdade de Ciências Sociais e Humanas da Universidade NOVA de Lisboa (NOVA FCSH)*

## Abstract

Synergies between globalization and knowledge economy were suggested to direct biomedical research towards economically-interested activities. In this context, research in malaria, a disease endemic to poverty, may be at a paradoxical stance. This study addresses this issue assessing whether malaria research is driven by the accumulation of economic and/or other forms of capital. Drawing upon academic and epistemic capitalism, malaria research is characterized through the analysis of all Web of science-indexed publications involving Portuguese organizations (1900-2014; n=467). First, data was systematized by content and bibliometric analyses. Subsequently, multiple correspondence analysis revealed a bi-dimensional landscape (who's publishing; what's published) and cluster analysis identified three profiles (beginners; local appropriations; global science). This study reveals the construction of Portugal's scientific system and unveils the assimilation of dominant modes of organizing, doing and thinking despite malaria's research low profit potential. Extending this approach to other biomedical fields can unravel the dimensions underlying science's (re)construction.

**Keywords:** capitalism, scientific practices, malaria

## Introduction

In 2015, there were approximately 212 million new cases of malaria, 429 thousand deaths, and almost half of the world's population was at risk of developing this pathology (World Health Organization, 2016). As such, malaria is a major threat for public health, particularly in geographies where it is endemic, mostly poor countries and populations, including regions of all former Portuguese territories. Despite these numbers, only 0.4% of all biomedical research focused on malaria research in 2004, with most studies being conducted in North America and Europe (Lewison and Srivastava, 2008)[2]. In Portugal, science has long contributed to the understanding of malaria. This has been attributed to the fact that malaria was endemic in continental Portugal until 1973, the year when malaria was considered to be eradicated by the World Health Organization (Bruce-Chwatt and Zulueta, 1977), and to the long-standing relations with Portugal's former territories, where malaria remains endemic. Indeed, the relevance of the scientific contribution of malaria research in Portugal can be revealed by the presence of Portuguese scientists in major international scientific grants and publication outlets (Ferreira, 2016). However, the social foundations of malaria research remain, for the most part, to be ascertained.

Aiming to address this knowledge gap, the present study is driven by the following research question: how has malaria research changed since the beginning of the 20th century in Portugal? This is a period characterized by deep transformations in science that have been described under academic and epistemic capitalism, and other theoretical backgrounds (see Hessels and van Lente, 2008 for a review). According to academic capitalism, capitalist dynamics are revealed in the increasing presence of economically-oriented practices in academic institutions. More specifically, the authors point to the participation of academic actors in market activities (e.g., patenting, spin-off companies) or development of market-like activities (e.g., competition for external grants, partnerships with industry) (Slaughter and Leslie, 1999; Slaughter and Rhoades, 2004). Epistemic capitalism extends this rationale to propose capitalism as a cultural way of producing, attributing and accumulating specific forms of worth, which are not necessarily monetary (e.g., symbolic capital associated with publications and grants) and that can be currently found both in academia and enterprises (Fochler, 2016). According to both traditions, pressures towards the embodiment of capitalist dynamics (conceptualized in strictly economic terms or going beyond these terms) are revealed in transformations of scientific organizations, practices, and culture (Fochler, 2016; Hackett, 1990; Slaughter and Leslie, 1999; Slaughter and Rhoades, 2004). During this period of time, other studies have also shown that pressures to pluralise science and address public interest issues have been brought up by civil society groups, for instance through new forms of participatory research, such as community-based research, science shops or consensus conferences (Brown et al., 2006; Epstein, 1996; Hess, 2016; Moore et al., 2011). As such, science will result from on-going struggles, coalitions, and repositioning of academic, corporate, governmental, and civil society actors.

In this scenario, the focus on malaria research is particularly pertinent. On the one hand, it addresses an acute infectious disease that has major impacts in global public health, and thus, could be an arena of both corporate and public interest. On the other, it focuses on a pathology that affects mainly poor countries and populations, and thus is not particularly attractive for investment by the pharmaceutical and/or biotechnology industry (Daems et al., 2014; Lezaun and Montgomery, 2015). Concomitantly, scientists, including malaria researchers, operate in a global, highly competitive scientific arena, that is mostly characterized by dominant modes of organizing, modes of doing, and modes of thinking. According to academic and epistemic capitalism, the organization of academic and scientific institutions tends to replicate private corporations; scientists are pushed into the production of both traditional academic yields (e.g. grants; papers), and the fulfilment of market opportunities, and other economic and social outputs, and the ethos of science is increasingly driven by competition and performance. Still, civil society groups have been contesting these dominant forms, with their action being more visible in environmental issues, but being also present in other areas, including the biomedical arena (Brown et al., 2006; Epstein, 1996; Hess, 2016; Moore et al., 2011). Within the field of malaria research, how these processes have been developing is, to the best of our knowledge, unstudied.

For this purpose, this study will scrutinize malaria research outputs, i.e., indexed scientific publications published between 1900 and 2014, to characterize the following layers: organizational (evaluating authorships and organizational affiliations); scientific practices (characterizing the types of papers; methodological approach and publication subject area); and culture of the scientific field (assessing performance indicators and the order of authors and co-authors). The mentioned indicators have been previously associated with the transformations of science and allow assessing for the presence of market-like activities (as revealed for instance in the presence or absence of partnerships with companies) and to characterize the significance of other forms of capital (as revealed for instance by performance indicators associated with publications). All mobilized variables are listed in Table 1. This characterization will allow us to address the following specific questions. 1) Which dimensions are underlying malaria research performed by Portuguese organizations? And, 2) do the profiles of malaria research reveal the previously reported transformations of science?

This paper will start by exploring these issues in malaria research outputs. This approach allows addressing the process of scientific construction through the imprinting of what is perceived as legitimate science developed by legitimate actors. For this purpose, we will carry out bibliometric and content analyses of research outputs. However, many before us have analysed changes in individual indicators in other contexts and drawing upon diverse theoretical traditions (see Hessels and van Lente, 2008 for a review). Nevertheless, within the study of malaria research, these analyses are limited to few, strictly descriptive, bibliometric studies (Fu et al., 2015; Garg et al., 2009; Gupta and Balaji, 2011; Lewison et al., 2002; Lewison and Srivastava, 2008; Rodrigues et al., 2000). Most importantly, previous studies focus on the independent analysis of individual indicators, and thus preclude an assessment of the multidimensional nature of knowledge production. In addition, the research design of these studies did not allow assessing whether and how the different layers and corresponding indicators interact with one another. The present study will overcome this knowledge gap via an integrative analysis of a wide variety of variables that draw upon previously reported indicators of science's transformations without establishing *a priori* which the most relevant dimensions for scientific production are. Going beyond simply analysing what changed in the specific context of malaria research (as previous studies did), we will carry out multiple correspondence analysis to specify, among all studied variables, which contribute to the most critical dimensions of malaria's scientific landscape (specific question 1). This analytical procedure is followed by a cluster analysis that will identify malaria research profiles and reveal whether the previously described transformations of science are also present in malaria research (specific question 2).

Altogether, our approach to the study of malaria research is particularly relevant since it proceeds with a relational multidimensional analysis to characterize the evolution of knowledge production in malaria in light of the above-described transformations of science. Thus, this approach allows addressing how knowledge production reflects the institutional conditions governing biomedical sciences in general and, malaria research, in particular. In addition, the counters of the Portuguese example, which remain unstudied, render it to be particularly pertinent. This is the case since Portuguese organizations link organizations from more developed S&T systems and their associated modes of scientific production (ways of organizing; ways of doing, and ways of thinking), with organizations from poor countries and regions where malaria remains endemic, such as regions of all former Portuguese territories.

The following sections systematize previous studies addressing the transformations of science and, more specifically, transformations at the organizational level; scientific practices' level; and cultural level. Whenever possible, this discussion focuses on modifications in life sciences, and, particularly, malaria research. The following section addresses the processual nature of science and its articulation with the chosen methodological approach. This opens up to the methodological section and, subsequently, to the results. A discussion immediately follows, in which the shortcomings of our research and future lines of study are outlined. Also, the major scientific inputs of this research as well as its social and scientific relevance are presented in the concluding remarks.

## The changing patterns of science

Presently, science is recognized, among many theoretical traditions, as an heterogeneous endeavour (see Hessels and van Lente, 2008 for a review), framed by on-going struggles, coalitions, and repositioning of academic, corporate, governmental, and civil society actors. Within academic and epistemic capitalism, the transformations of the scientific landscape have been argued to result from synergies between globalization and knowledge economy that directed science towards economically–interested market and market-like activities (academic capitalism) and/or to the attainment of other forms of capital such as the symbolic capital associated with performance indicators (epistemic capitalism) (Fochler, 2016; Hackett, 1990; Slaughter and Leslie, 1999; Slaughter and Rhoades, 2004). This is not to say that the interconnections between the markets and academia are a recent phenomenon, quite the contrary, they have been present for a long time (Blumenthal et al., 1986; Etzkowitz, 1983; Weiner, 1987). However, their prevalence and relevance have significantly increased since the 1970s-1980s. It is precisely in these years that the commercialization of life sciences becomes more recognizable. In the wake of the discovery and application of recombinant DNA molecule techniques, academic, corporate, and political actors were confronted with the immense possibilities associated with new sources of funding, faster technology transfer to industry, incentives for innovation, and competitive advantage in (inter) national markets. However, they were simultaneously faced up against the potential detrimental impacts of such connections, including a redirection of research agendas, the presence of conflicts of interest on the research being developed, and the erosion of the open science model (Krimsky et al., 1991; Krimsky and Nader, 2004). Most noticeably in areas such as environmental issues, but also in biomedical research and others, participatory research and diverse forms of demonstration and direct action have challenged the dominant modes of scientific production (Brown et al., 2006; Epstein, 1996; Hess, 2016; Moore et al., 2011). As such, the science that is produced at particular times and spaces results from the interactions of this multitude of actors.

The period this paper addresses has witnessed transformations of scientific and academic organizations and in the relationships these organizations establish with the contexts in which they operate (ways of organizing). Additionally, the epistemological principles guiding scientific practices have been changing. Presently, an increasing demand for contributions to national, corporate or public goals has led to an intensification of multi-, inter-, and/or transdisciplinary scientific practices as well as to research primarily guided by its application (applied research) or, at least inspired, by knowledge's future application (use-inspired research)[3] (Martin, 2011; Stokes, 2011) (ways of doing). Interestingly, between 1995 and 2009, big pharma increased R&D investment while presenting small decreases in total publication numbers. However, the same companies steadily increased the publication rate in disciplines more oriented to clinical application or health services, a pattern that is present in infectious diseases. Also increasing, was the number of external collaborations in publications (Rafols et al., 2014). What these data suggest is a transformation of the research that is developed by big pharma. Rafols and colleagues describe it as a shift from basic science to clinical fields, from research in-house to increasing outsourced development. These results are consistent with the increasing relevance of public-private partnerships in drug development for neglected tropical diseases, such as malaria (Lezaun and Montgomery, 2015).

Finally, the codes, norms and values that underlie scientific practices, have also been under relevant transformations (ways of thinking). Some authors have argued that these changes, revealed for instance in the relation between scientists and their work or the relation among scientists (Hackett, 1990; Hackett, 2005; Krimsky and Nader, 2004), reflect the assimilation of a capitalist ethos that also pervades non-profit driven scientific practices (Fochler, 2016; Kleinman, 2010) and can be illustrated by the significance given by scientists and their organizations to performance-oriented models of research (Fochler, 2016).

In the following sub-sections, this paper presents studies focusing on specific indicators of science's transformations at the organizational, practices, and cultural level. These will be discussed in the context of life sciences and, whenever possible, malaria research.

### *Scientific organizations*

As described by the academic capitalism literature and others (see Hessels and van Lente, 2008 for a review), the growth of international partnerships is a common example of organizational transformations. This is a long standing trend that was severely strengthened in the last decades (Coccia and Wang, 2016; Frame and Carpenter, 1979; Glänzel, 2001; Hicks and Katz, 1996; Luukkonen et al., 1992).

As for the Portuguese case, its research presents one of the largest rates of international collaborations in scientific articles since 1980s, with the life sciences presenting a relevant role in this growth (Patrício, 2011; Santos Pereira, 2002). Several factors have been suggested to contribute for these numbers. First, Portugal is a small European country with a small, but growing, scientific community, with still reduced scientific outputs. Also, the collaborations of Portuguese organizations follow the overall patterns of Portugal's geographic, linguistic, historical, cultural, economic or political affinities (Frame and Carpenter, 1979; Luukkonen et al., 1992). In addition to the United Kingdom and Spain, Portugal also maintains strong scientific collaborations with its former territories, particularly Brazil (Patrício and Santos Pereira, 2015). In these settings, this study will go beyond simply addressing internationalization patterns, to characterize the specific countries with which Portuguese organizations have been collaborating with, and how these collaborations have been developing.

The increasing participation of diverse organizations in scientific production is yet another organizational transformation that is important to tackle. In fact, an increasing heterogeneity in papers' authorships has been shown in diverse geographies and scientific fields (Godin and Gingras, 2000; Hicks and Katz, 1996; Martin, 2011), with biomedical organizations (Godin and Gingras, 2000; Hicks and Katz, 1996) and industry (Godin and Gingras, 2000) increasing their relevance. In spite of these data, to the best of our knowledge, no studies have mapped the interconnections between academia and other organizations in Portugal in any area of scientific research. Nonetheless, several studies confirm the presence of diverse organizational types in malaria research outside Portugal (Daems et al., 2014; Lezaun and Montgomery, 2015; Pollock, 2014; Trouiller et al., 2002).

Most importantly, the impacts of these diversified country and organizational profiles on the scientific practices *per se* have not been previously assessed.

### *Scientific practices*

Within the framework of academic capitalism, a trend towards increasing application of scientific production has also been discussed (Hackett, 1990; Hackett, 2001; Slaughter and Leslie, 1999; Slaughter and Rhoades, 2004). However, if this trend seems to be present when focusing on a specific area of research (Martin, 2011), studies reveal some lack of consistency (Hicks and Katz, 1996)[4]. This is possibly resulting from conceptualization and/or methodological differences. Since our study focuses exclusively on a specific sub-field of biomedical sciences, i.e. malaria research, the papers to be analysed will always be at least inspired by a potential application (Stokes, 2011). This being said, we will go one step forward in this characterization to address the studies' methodological design. More specifically, within experimental papers, we can ascertain whether publications are solely focused on describing pathophysiological mechanisms of disease without any translation to cellular or animal models (the quest here, though use-inspired, is focused on the understanding of specific phenomena or processes). We will also ascertain whether the research also involves any type of translation to cellular or animal models, but not to human subjects; or, finally, whether it involves human subjects (the quest here is the translation of the understanding of specific phenomena or processes to human subjects). This categorization, intending to recapitulate the multiple steps of the translational process of biomedical research, should allow us to understand whether malaria research focuses on the understanding of its pathophysiological mechanisms or the translation and potential application of this knowledge to the inhibition or blockage of pathophysiological progression. To the best of our knowledge, this has not been previously evaluated. Still, previous studies have suggested relevant characteristics of malaria research that we will consider in our study. Among these is the presence of a broad range of publication types (from non-experimental types such as reviews or editorials; to empirical studies reported as conference papers and scientific articles) (Meena and Nagarajan, 2013) and publication areas (from medicine, to epidemiology or pharmacology, to subfields of malaria vaccine research) (Garg et al., 2009; Garg et al., 2006; Gupta and Balaji, 2011). However, as these studies aimed at describing the characteristics of malaria research, and not to address whether and how these characteristics reveal the on-going transformations of science, their inputs, important as they are, cannot answer the questions guiding the present study.

### *The culture of science*

Finally, regarding the scientific ethos, we will focus on the presence of performance-oriented models of research as revealed by the increasing significance attributed to journals' impact factors and articles' number of citations[5]. If, within the biomedical community, these indicators are perceived as proxies of journals' quality (Adam, 2002; Saha et al., 2003) or, at least, reliable sources of legitimization of one's work (Rushforth and de Rijcke, 2015), in fact, they were reported to present a number of limitations and biases[6] and, thus, can only give a partial assessment of scientific production (Gläser and Laudel, 2007; Weingart, 2010).

Nevertheless, citation-based performance indicators have become highly pervasive and this was suggested to result from the market-like structuration of academic and scientific organizations that instigated project-oriented research and an ever increasing relevance of what is understood as highly performative science (Kleinman and Vallas, 2001; Krimsky and Nader, 2004; Luukkonen et al., 1992; Sigl, 2015; Ylijoki, 2003). This happens in a context of an increasing number of graduates and, as previously said, decreasing long-term senior positions and increasing short-term positions, generally associated with third-party funded projects. This means that scientists, today, need to balance the participation in research projects that are collaborative endeavours, under a highly competitive environment that requires them to be the single most performant researcher (Muller, 2012). In biomedical sciences, this means not only publishing the highest amount of papers, in the highest ranked journals, receiving the highest number of citations, but also being either the first or the last author of such publications. To note that while these authorship positions and authors contributions are not a formalized system that is transversal to all fields of science, it was recently shown that some characteristics of authorships are shared among diverse scientific areas of expertise: first and last authors typically contribute to more tasks than middle authors (Larivière et al., 2016). Within the biomedical field, the scientist that performed the most central work is the first author; the head of the laboratory (the "funder" of the research, and the one responsible for critical mentoring) is the last author; and the other co-authors performed smaller parts of the research or gave some intellectual input (Dance, 2012; Muller, 2012). With these indicators, we do not intend to characterize the best/most performant research but rather to evaluate what type of research is published in journals perceived to be the most relevant, and thus, that mostly contribute to establish perceptions on what the most pertinent type of research is.

In what concerns previous studies in malaria research, it was shown that chemical and pharmacology studies were the most cited, while public health research was the least cited[7] (Gupta and Balaji, 2011). However, the relations between perceived performance (impact factors; citations, and authorship positions) and application patterns, internationalization or actors heterogeneity were never assessed. This study will cover these issues, analysing whether malaria profiles are associated with the above-mentioned performance indicators.

## The process of (re)constructing malaria research landscape: linking theory to methodology

It is our understanding that science results from on-going struggles, coalitions, and repositioning of academic, corporate, governmental, and civil society actors. If this is the case, the transformations of scientific organizations, practices and culture, cannot be assumed as central tendencies. In other words, the transformations of science should not be studied as static notions that result from specific contexts or actions, but rather as being part of an interdependence system of relations. As such, malaria's scientific landscape will be characterized not through the evaluation of any specific indicator or the independent characterization of several indicators (Hicks and Katz, 1996; Martin, 2011), but rather, through the integrative characterization of indicators of the organization, practices and culture of science (see Table 1). This characterization will allow for the identification of the most relevant dimensions of malaria research and of the variables that underlie them. The dimensions that compose this scientific landscape will be described as axes of variation presenting opposing poles with contrasting features. At any given point in time, actors' struggles, coalitions, and repositioning can alter the balance between the opposing poles and favour a specific pole over the other. Consequently, a diversified set of research profiles will be located across the spectrum of the axes that structure the research plan. This framework, previously mobilized to address modifications in the culture of academic science (Hackett, 1990), is rooted in the processual nature of the (re)construction of the scientific landscape. Also, it allows to go beyond simply describing the individual transformations of science, to identify and characterize the most relevant dimensions (axes of variation), and, subsequently, to work towards a deeper understanding of what compelled these changes.

As such, understanding science as a multilayer relational process imposes that its analysis 1) concomitantly addresses indicators of the diverse levels at stake, 2) assesses whether and how the identified variables relate to one another (i.e., assesses the underlying relational structure among the different variables), and 3) identifies diverse profiles of research on that structure. This is not possible to achieve via uni- or bivariate statistics but can be achieved via specific multivariate techniques that address the multidimensionality and relational characteristics of the observed processes.

Going beyond previous studies analysing how specific indicators change, our methodological approach draws upon the influential work of the French sociologist Pierre Bourdieu, and many others (Benzécri, 1992; Bourdieu, 1979; Bourdieu, 1984; Bourdieu, 1989; Bourdieu, 1999; Greenacre and Blasius, 2006; Roux and Rouanet, 2004; Roux and Rouanet, 2010). As such, this paper combines multiple correspondence analysis (to unravel the structure of malaria's scientific landscape - specific question 1), with cluster analysis (to identify specific profiles of research and whether they replicate or diverge from the dominant modes of organizing; practising and thinking in science - specific question 2).

## Methodology

This study starts by identifying the scientific publications that fulfil the following criteria: 1) are indexed in Web of Science (Thomson Reuters), a private database that gathers scientific publications since 1900, and is perceived within the biomedical community as one of the *loci* of maximum legitimization of research (Adam, 2002; Saha et al., 2003); 2) include the words "Malaria" and/or "Plasmodium", the causative agent of malaria[8], either in the title or summary; 3) were published between 1900 and 2014; and 4) are (co-)authored by researchers working at Portuguese organizations. These publications reveal the participation of Portuguese organizations in the international scientific community. This task was performed between January and March 2015 at the platform http://apps.webofknowledge.com/. A total of 472 publications fulfilled the above-mentioned criteria. After a careful analysis of the publications' content, 5 papers were removed from our corpus of analysis. This was the case since 1 of these publications did not focus on malaria research, and the other 4 did not present authors affiliated with Portuguese organizations.

In the second stage of research, we combined the use of bibliometric indicators, a commonly used strategy to empirically address the transformations of the scientific landscape (Hicks and Katz, 1996; Martin, 2011), with content analysis of the same publications (n=467), a strategy aiming for a deeper understanding of the publications at stake (Weber, 1990). This approach provides us a detailed characterization of papers' date of publication; participating organizations; developed scientific practices; and underlying culture of science. The specific variables and categories within each layer of analysis can be found in Table 1.

Following, the configuration of the scientific landscape of malaria research was established

**Table 1.** Layers of analysis, variables, and categories

| **Layers of Analysis** | **Variables** | **Categories** |
|---|---|---|
| **Date of publication** | **Year of publication** | Before 1995<br>1995-1999<br>2000-2004<br>2005-2009<br>2010-2014 |
| **Organization** | **Number of authors** | 1<br>2-4<br>5-9<br>10 or more |
| | **Country of organizational affiliations** | Portugal*<br>International** |
| | **Collaboration with former Portuguese territories** | Yes<br>No |
| | **Collaboration with Europe, North America and Oceania** | Yes<br>No |
| | **Collaboration with countries with endemic malaria and not former Portuguese territories** | Yes<br>No |
| | **Number of different types of organizational affiliation** | 1<br>2<br>3 or more |
| | **Affiliation: academic or research organization** | Yes<br>No |
| | **Affiliation: hospital** | Yes<br>No |
| | **Affiliation: state departments/governmental organization** | Yes<br>No |
| | **Affiliation: non-governmental organizations or non-profit corporations** | Yes<br>No |
| | **Affiliation: industry** | Yes<br>No |
| | **Affiliation: museum** | Yes<br>No |
| **Practices** | **Publication subject area** | Infectious diseases and Tropical Medicine<br>Molecular & Cellular Biology and Immunology<br>(Bio)chemistry;<br>Pharmacology and Biotechnology<br>Medicine and Public Health<br>Multidisciplinary<br>Others |
| | **Paper type** | Meeting abstracts<br>Research articles<br>Reviews/discussions<br>Others |

**Table 1 cont.**

| | | |
|---|---|---|
| | **Methodology** | Non-experimental<br>No live models§<br>Cellular & animal models§§<br>Translational research§§§ |
| **Culture** | **Impact factor&** | Under 2<br>Between 2 and 10<br>Above 10 |
| | **Citations$** | Top 10% (most cited papers)<br>]10-25%]<br>]25-50%]<br>]50-100%] (least cited papers) |
| | **First authorship: Portuguese#** | Yes<br>No |
| | **Last authorship: Portuguese##** | Yes<br>No |

Note: *: publications authored by researchers working exclusively in Portuguese organizations; **: publications authored by researchers working in Portugal and elsewhere; §: chemical and/or mathematical studies; §§: Non-human live models of research including cellular and/or animal models; §§§: studies with human subjects; &: Journal citation reports (JCR) impact factor in 2014; $: number of citations until 2014; #: the first author is affiliated with a Portuguese organization; ##: the last author is affiliated with a Portuguese organization.

through the simultaneous analysis of its different components (variables) and of the relations established between them. Multiple correspondence analysis (MCA), a technique that uncovers the underlying structure of a multivariate space, through geometric data modelling (Roux and Rouanet, 2004; Roux and Rouanet, 2010), was used to establish the underlying dimensions of the scientific landscape without imposing any previous structure. As any multivariate technique, the MCA aims at clarifying a complex data structure, and it does so through the identification and characterization of the main dimensions (i.e., axes of variation with opposing poles) supporting that structure. The identified dimensions are those that account for the most variance, thus explaining the most relevant relations between subjects (i.e., papers) and categories of the variables. This is the case since the purpose of MCA is to reduce the multidimensionality of the data while unravelling its underlying relational structure. As such, "Each dimension added to the solution increases the explained variance of the solution, but at a decreasing amount (i.e., the first dimension explains the most variance, the second dimension the second greatest, etc.)" (Hair et al., 2013: 528).

Next, we proceeded with a first identification of research profiles (interpreted from the geometry of the interrelations between the subjects and categories) and, subsequently, operationalized these profiles via a cluster analysis based on the MCA's object scores for each identified dimension. The further characterization of the identified clusters (groups of subjects that share certain characteristics) was accomplished by the cross tabulation with the initial variables that represent the scientific landscape of malaria research and other relevant dimensions, such as the times and spaces of science production. Pearson chi-square tests assessed the independence between nominal variables, and adjusted standardized residuals assessed associations between categories of nominal variables.

Statistical analysis was performed with IBM SPSS Statistics, version 20, statistical package.

## Results

### *Researching malaria in Portugal: who is researching malaria and what is being produced in malaria research*

We started by performing a MCA in order to reduce the complexity of the data, and establish

**Table 2.** Discriminatory dimensions of the scientific landscape of malaria research.

| Variables | Discrimination measures | |
|---|---|---|
| | Dimension 1 | Dimension 2 |
| Country of organizational affiliation | 0.646 | 0.006 |
| Collaboration with Europe, North America, and/or Oceania | 0.556 | 0.107 |
| Number of authors | 0.496 | 0.170 |
| First authorship: Portuguese | 0.350 | 0.027 |
| Last authorship: Portuguese | 0.330 | 0.049 |
| Number of different types of organizational affiliations | 0.303 | 0.004 |
| Methodology | 0.156 | 0.673 |
| Paper type | 0.183 | 0.643 |
| Collaboration with former Portuguese territories | 0.013 | 0.204 |
| Impact factor | 0.074 | 0.175 |
| Citations | 0.167 | 0.084 |
| Publication subject area | 0.120 | 0.051 |
| Collaboration with countries with endemic malaria which are not former Portuguese territories | 0.238 | 0.018 |
| Active total | 3.033 | 2.210 |

Note: Shaded cells correspond to an above average contribution to the definition of the dimension. For dimension 1, the average contribution of the variables is 0.279, and for the second dimension the average contribution is 0.170 (dimension's active total/number of active variables). Variables that are not significantly contributing to the discrimination of either dimension (i.e., that do not present any shaded cells) are still kept in the analysis due to their categories' significant contribution (see Figure 1, Supplementary Table 1).

the dimensions that mostly structure the space of malaria research. The following variables discriminated the observations into two main dimensions (Table 2).

This analysis reveals that the variables contributing the most for the structure of the first dimension are: country of organizational affiliation; collaboration with Europe, North America, and/or Oceania; number of authors; first and last authorships: Portuguese; and number of different types of organizational affiliations. These variables indicate that dimension 1 is mainly focusing on who produces malaria research. As for dimension 2, the variables contributing the most are: methodology; paper type; collaboration with former Portuguese territories; impact factor; and number of authors. In this case, the variables underlying dimension 2 are mostly concerned with the types of publications being published.

Once having recognized what the two dimensions mostly refer to, and since we understand these dimensions as axis of variation, we will now specifically assess what the opposite poles of each dimension are. This will allow us, in the following analytical stage, to interpret more clearly the meaning of the profiles according to their positioning on the scientific landscape. For this purpose, we will proceed with the analysis of the variables' categories and their relative positioning in the identified research plane (see Supplementary Table 1 for this analysis).

The combined evaluation of the contribution of both variables and categories is depicted in Figure 1. This analysis led us to label dimension 1 as "Who's publishing", ranging from small (negative coordinates) to high heterogeneity of contributors (positive coordinates), and dimension 2 as "What's being published", ranging from translational science (negative coordinates) to non-experimental science (positive coordinates). This analysis addresses specific question 1, i.e., which dimensions are underlying malaria research performed by Portuguese organizations?

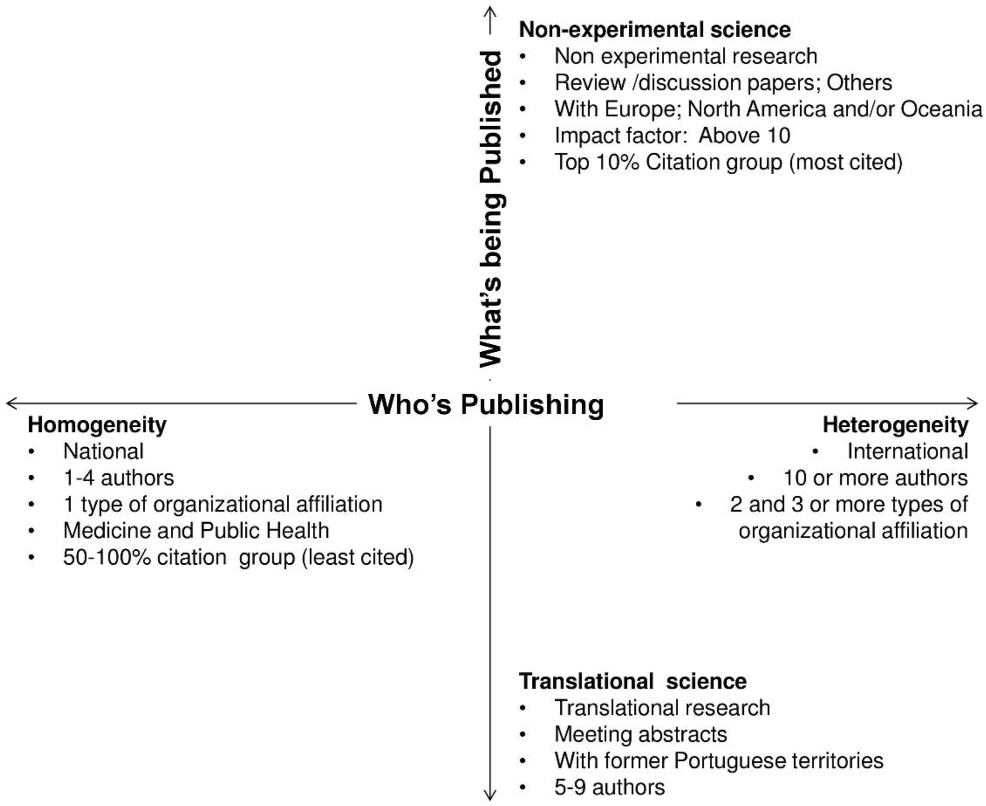


**Figure 1.** Bi-dimensional representation of the scientific landscape of malaria research. Dimension 1 depicts "Who's publishing", with its negative coordinates being characterized by a profile of homogeneity, while its positive coordinates present a profile of heterogeneity. Dimension 2 depicts "What's being published", with its negative coordinates being characterized by a profile of translational research, while its positive coordinates present a profile of non-experimental science.

Once having characterized the bi-dimensional structure of malaria research, in the next section we will identify and characterize the specific profiles of malaria research via a cluster analysis.

### *Profiles of malaria research in Portugal*

The characterization of malaria research profiles was accomplished through a hierarchical cluster analysis based on the multiple correspondence analysis' object scores. This allowed operationalizing and characterizing more clearly the revealed profiles. More specifically, and given the methodological options undertaken and previously described, this analysis suggests the presence of three profiles of malaria research located along a bi-dimensional landscape[9].

As shown in Table 3 and depicted in Figure 2, there is a high probability of publications grouped in cluster 1 being 1) review or discussion papers (and other types of papers), and thus papers without any empirical data. Also, there is a high probability that these publications 2) present high impact factors (10 or above); 3) are written by a relatively small number of authors for the context of biomedicine (4 or less). Also, there is a high probability that these authors are 4) mainly affiliated with Portuguese organizations; and 5) present no more than one type of organizational affiliation (Table 3). Overall, there is a high probability that this cluster includes non-experimental publications in journals with high impact factors and in which the contributors are highly homogeneous (as perceived by its placement on the second quadrant of Figure 2). A quick note to say that this cluster is associated with publications in journals specifically dedicated to reviews and discussion papers, which publish papers that are highly cited, and, thus, present higher than average impact factors. In spite of these journals' high impact factors, no associations were found with any of the categories of citation numbers. This is indicative that the specific publications that were analysed did not have such a high pervasiveness in the malaria field.

Publications in Cluster 2 have a high probability of 1) being written by 2 to 4 authors, 2) presenting contributors affiliated in Portuguese organizations that are first and last authors, and 3) have additional contributors from former Portuguese territories, but neither from European, North American and/or Oceanian countries, nor from countries where malaria is endemic and which are not former Portuguese territories (Table 3). These publications are associated with 4) only one type of organizational affiliation, 5) Medicine and Public Health, 6) translational methodological approaches (i.e., with the participation of human subjects), and 7) meeting abstracts (not full publications). Also, these papers are associated with smaller impacts, as they show a high probability of belonging to 8) the least cited group of papers (50%-100%), and of 9) being published in journals with low impact factors (less than 2). These "performance profiles" seem to be consistent

**Table 3.** Characterization of malaria research outputs per scientific profile.

| | | Cluster 1 (n=60) | Cluster 2 (n=131) | Cluster 3 (n=276) | Total |
|---|---|---|---|---|---|
| **Number of authors** | 1 | **5.8*** (15.0%) | 0.6 (3.8%) | -4.6* (0.0%) | 3.0% |
| | 2-4 | **7.4*** (63.3%) | **5.4*** (42.0%) | -9.9* (8.3%) | 24.8% |
| | 5-9 | -4.7*(18.3%) | 0.9 (49.6%) | **2.4*** (51.1%) | 46.5% |
| | 10 or more | -4.2 (3.3%) | -6.5* (4.6%) | **8.8*** (40.6%) | 25.7% |
| **Country of Affiliation** | Portugal | **3.2*** (40.0%) | **13.3*** (65.6%) | -14.3* (0.4%) | 23.8% |
| | International | -3.2* (60.0%) | -13.3* (34.4%) | **14.3*** (99.6%) | 76.2% |
| **Col. with former PT territories** | Yes | -3.6* (3.3%) | **3.5*** (31.3%) | -0.8 (19.6%) | 20.8% |
| | No | **3.6*** (96.7%) | -3.5* (68.7%) | 0.8 (80.4%) | 79.2% |
| **Col. with Europe, North America and Oceania** | Yes | -1.5 (55.0%) | -16.6* (4.6%) | **16.1*** (93.5%) | 63.6% |
| | No | 1.5 (45.0%) | **16.6*** (95.4%) | -16.1* (6.5%) | 36.4% |
| **Col. with countries with endemic malaria and not former PT territories** | Yes | -1.8 (11.7%) | -6.6* (0.8%) | **7.2*** (31.5%) | 20.3% |
| | No | 1.8 (88.3%) | **6.6*** (99.2%) | -7.2* (68.5%) | 79.7% |
| **Number of types of organizational affiliation** | 1 | **3.7*** (73.3%) | **6.8*** (76.3%) | -8.8* (34.1%) | 51.0% |
| | 2 | -2.5* (25.0%) | -5.5* (19.8%) | **6.7*** (52.2%) | 39.6% |
| | 3 or more | -2.2* (1.7%) | -2.6* (3.8%) | **3.9*** (13.8%) | 9.4% |
| **Publication subject area** | Infect diseases/Trop Med | -0.3 (55.0%) | 0.3 (58.0%) | -0.1 (56.5%) | 56.7% |
| | Mol & Cell Biol/Immunol | 0.1 (8.3%) | -1.7 (4.6%) | 1.4 (9.4%) | 7.9% |
| | (Bio)chem/Pharm/Biotech | 1.0 (15.0%) | -2.2* (6.1%) | 1.4 (13.0%) | 11.3% |
| | Medicine and Public Health | 0.2 (6.7%) | **4.8*** (14.5%) | -4.6* (1.8%) | 6.0% |
| | Multidisciplinary | -1.1 (10.0%) | -1.2 (11.5%) | 1.8 (17.0%) | 14.6% |
| | Others | 0.7 (5.0%) | 1.4 (5.3%) | -1.8 (2.2%) | 3.4% |
| **Paper type** | Meeting abstracts | -3.0* (0.0%) | **6.5*** (26.7%) | -4.0* (6.5%) | 11.3% |
| | Research articles | -13.6* (1.7%) | -0.2 (73.3%) | **9.4*** (89.9%) | 73.9% |
| | Reviews/discussions | **16.3*** (60.0%) | -3.9* (0.0%) | -7.5* (0.0%) | 7.7% |
| | Others | **10.1*** (38.3%) | -3.7* (0.0%) | -3.5* (3.6%) | 7.1% |
| **Methodology** | Non-experimental | **21.0*** (98.3%) | -4.9* (0.8%) | -9.8* (0.4%) | 13.1% |
| | No live models | -0.7 (0.0%) | 0.2 (0-8%) | 0.3 (0.7%) | 0.6% |
| | Cellular & animal models | -6.7* (1.7%) | 0.7 (44.3%) | **3.9*** (48.9%) | 41.5% |
| | Translational | -7.5* (0.0%) | **2.6*** (54.2%) | **2.7*** (50.0%) | 44.8% |
| **Impact Factor** | Under 2 | -0.8 (13.8%) | **5.7*** (34.5%) | -4.6* (10.9%) | 17.5% |
| | 2-10 | -1.8 (67.2%) | -3.3* (65.5%) | **4.2*** (83.2%) | 76.5% |
| | Above 10 | **4.5*** (19.0%) | -3.2* (0.0%) | -0.2 (5.8%) | 6.0% |
| **Citations** | Top 10% (most cited) | 0.1 (10.0%) | -3.7* (1.5%) | **3.3*** (13.4%) | 9.6% |
| | ]10-25%] | 0.0 (15.0%) | -3.1 (6.9%) | **2.8*** (18.8%) | 15.0% |
| | ]25-50%] | -0.6 (21.7%) | -2.8* (16.0%) | **3.0*** (30.1%) | 25.1% |
| | ]50-100%] (least cited) | 0.5 (53.3%) | **6.8*** (75.6%) | -6.6* (37.7%) | 50.3% |
| **First authorship: Portuguese** | Yes | 1.0 (73.3%) | **8.4*** (96.9%) | -8.4* (52.5%) | 67.7% |
| | No | -1.0 (26.7%) | -8.4* (3.1%) | **8.4*** (47.5%) | 32.3% |
| **Last authorship: Portuguese** | Yes | 0.7 (66.7%) | **9.4*** (96.2%) | -9.1* (45.7%) | 62.5% |
| | No | -0.7 (33.3%) | -9.4* (3.8%) | **9.1*** (54.3%) | 37.5% |

Note: Values are expressed as adjusted standardized residuals and percentage within specific clusters. * Denotes statistical significance ($|Z| > 1.96$; level of significance of 0.05); bold indicates positive significant probability of association. Col.: Collaboration; PT: Portuguese; Infect diseases/Trop Med: Infectious diseases and Tropical Medicine; Mol & Cell Biol/Immunol: Molecular and Cellular Biology and Immunology; (Bio)chem/Pharm/Biotech: Biochemistry; Chemistry, Pharmacology; and Biotechnology.

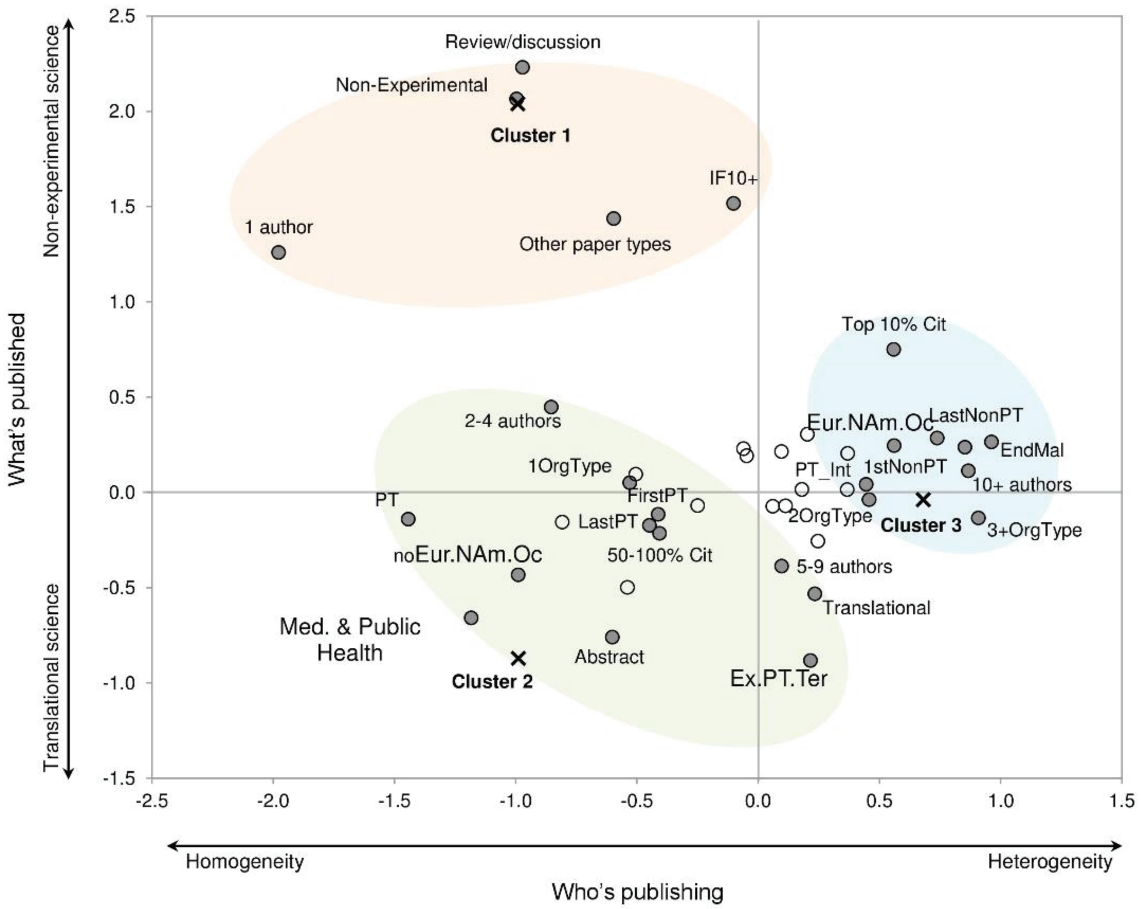


**Figure 2.** The scientific landscape of malaria research.
The first dimension illustrates who's publishing (ranging from homogenous to heterogeneous publications); the second dimension illustrates what's being published (from translational science to non-experimental publications). Shadings correspond to Cluster 1 (top, left) (n=60); Cluster 2 (bottom, center) (n=131) and Cluster 3 (middle, right) (n=276). IF10+: Impact factor above 10; Top 10% Cit: Top 10% citation group (most cited); 50%-100% Cit: ]50-100%] citation group (least cited); PT: Country of affiliation Portugal; PT_Int: Country of affiliation Portugal and others; FirstPT: First author from Portuguese organization; LastPT: Last author from Portuguese organization; 1stNonPT: First author from non-Portuguese organization; LastNonPT: Last author from non-Portuguese organization; 1OrgType: 1 type of organizational affiliation; 2OrgType: 2 types of organizational affiliation; 3+OrgType: 3 or more types of organizational affiliation; Ex.PT.Ter: collaboration with former Portuguese territories; Eur.NAm.Oc: Collaboration with Europe, North America and Oceania; noEur.NAm.Oc: No collaboration with Europe, North America and Oceania; EndMal: Collaboration with countries with endemic malaria and not former Portuguese territories; Med. & Public Health: publication on Medicine and Public Health area.

with the fact that this cluster has a high probability of presenting meeting abstracts and full papers in Medicine and Public Health, an area of research that was previously associated with low citations in malaria research (Gupta and Balaji, 2011). Overall, this cluster is characterized by its contributors' homogeneity and translational low impact research (placement on the third quadrant (Figure 2).

Lastly, papers in cluster 3 have a high probability of being co-authored by diversified profiles of authors and organizations. More specifically, these papers present a high probability of 1) being written by 5 or more authors; 2) presenting 2 or more types of organizational affiliations, that are based not only in Europe, and of North America and/or Oceania, but also in countries where malaria is endemic (and which are not former Portuguese territories) (Table 3). Methodologically, these publications have a high probability of 3) encompassing human subjects and/or cellular and animal models, and thus represent a use-inspired research which stands either very close (translational research) or relatively close (cellular and animal models) to a strict applied model of scientific research. Additionally, this cluster has a high probability of 4) including papers whose first and/or last authors are not working in Portuguese organizations, 5) being published in journals with moderate to high impact factors, and 6) being among the 50% most cited papers, which includes the top 10% most cited publications (Table 3). These results denote that papers in Cluster 3 do not tend to present major inputs from Portuguese organizations, but rather that Portuguese organizations and authors had, for the most part, less important contributions. Altogether, this profile is associated with relatively high impact and heterogeneity regarding the papers' contributors (as perceived by this cluster's placement on the intersection of the first and fourth quadrants (Figure 2)).

Overall, these results allow us to identify the presence of three profiles of malaria research located along a bi-dimensional landscape that opposes homogeneous to heterogeneous contributions (Cluster 3), and translational (Cluster 2) to non-experimental science (Cluster 1). In addition, the analysis of these data starts to address specific question 2 (i.e., do the specific profiles of malaria research reveal the previously reported transformations of science?).

In the next section, we will further characterize these practices to evaluate whether the profiles now identified are associated with the date of publication or the organizational types where scientific production took place.

### *Times and spaces of scientific production*

We started by testing whether the previously identified scientific profiles of malaria research were associated with the publication date, and types of organizational affiliations.

On the one hand, we found statistically significant differences among the clusters regarding the time frame in which the papers were published ($X^2_{(8)}$=18.146; p=0.020). Publications in Cluster 1 are associated with earlier dates (before 1995)[10]; Cluster 3 with more recent ones (from 2010 to 2014)[10], and Cluster 2 with papers published in the meantime (between 2005 and 2009)[10]. These data show that malaria research profiles are not independent of the date of scientific production.

On the other hand, we found statistically significant differences among the clusters regarding the organizational types participating in these publications ($X^2_{(2)}$=14.309; p=0.001; $X^2_{(2)}$=28.463; p<0.001, for the participation of universities and research institutions, and of hospitals and governmental organizations or departments, respectively). Moreover, as identified earlier, the papers grouped in Cluster 3 are associated with collaborations that are more diverse. As such, it does not come as a surprise that a significant relation was found between Cluster 3 and several organizational types, namely university and research institutions[11]; hospitals[11]; governmental organizations or departments[10]; and industry[11]. In addition, this cluster is not associated with the participation of non-governmental organizations or non-profit corporations, whose presence is residual in our corpus of analysis (1.7% of all papers). Knowing that research articles mostly characterize this specific cluster, this cluster more concretely adheres to the patterns of empirical malaria research recognized by peers. Confirming its location in the scientific landscape, these are practices that are highly heterogeneous in terms of contributions, including not only the more traditional spaces of scientific production, but also revealing that even in malaria research, the participation of biotechnological and pharmacological industry is emerging. Altogether, these data show that malaria research profiles are not independent of the spaces of scientific production.

## Discussion

### *Looking through the scientific landscape of malaria research*

This study reveals that the scientific landscape of malaria research is structured along two major dimensions (Figure 1). The first dimension explains the most relevant relations found in our data. This dimension concerns the actors of malaria research and ranges from a homogeneous to a heterogeneous composition. At a second level, presenting a lower but significant explanatory power, we found the papers that were published, with opposing non-experimental and translational poles. It is in this bi-dimensional plane that we have identified three scientific profiles of research. These profiles result from actors' struggles, coalitions, and repositioning taking place between 1900 and 2014. Noticeably, these profiles reflect very consistently the specificities of the Portuguese context, which we will now discuss.

Firstly, 98.5% of all Web of science-indexed malaria papers were published after 1995, which is very consistent with the development of Portuguese scientific system. In fact, if the most known scientific organizations that develop malaria research in Portugal were founded before the Portuguese revolution in 1974, it was only in the 1990s that Portugal presented significant growth of its major indicators of science and technology, significantly reducing the distance to the European Union levels (Rodrigues, 2015). It was also in this decade that Portugal had its first Ministry of Science (1995) and that the current national funding agency for science, technology, and innovation, the Foundation for Science and Technology, was founded (succeeding, in 1997, the earlier Junta Nacional de Investigação Científica e Tecnológica (1967)). It was also during the 1990s that public policies specifically targeting internationalization of science revealed a significant growth, and that policies targeting links between academia and industry were implemented (Rodrigues, 2015). In summary, the major international developments revealed by the analysed Web of science-indexed publications seem to be framed, at least partially, by the national context.

Secondly, the types of papers that were published, as well as the role that Portuguese-affiliated scientists have in them, are very revealing of the context of scientific production in Portugal. The first profile ("Beginners", Cluster 1), is associated with less recent reviews and discussion papers, mostly written by scientists affiliated with Portuguese organizations. This can be interpreted as an indication of an incipient internationalization of science. This implies that, in the earlier years of indexed-outputs of malaria research, publications were mostly characterized by an "experimental void" and rather discussed and reviewed others work.

The second profile, "Local appropriations", is associated with indexed outputs in which there is a high probability of Portuguese scientists assuming the most relevant positions in terms of authorships (first and last), and collaborations with scientists affiliated in organizations of former Portuguese territories. These studies are also associated with "Medicine and Public Health" and with the participation of human subjects with and without malaria, whose samples were most probably accessed through the collaborations with former Portuguese territories where malaria remains endemic. Importantly, these empirical studies are associated with "Meeting abstracts". This reveals that there is a high probability of studies included in the second profile to be not quite finalized, but rather on-going projects that could be "translated" into full papers, on a later point in time. Even though other factors could also play a role, it is our understanding that features such as the association of Cluster 2 with "Meeting abstracts" and with publications in "Medicine and Public Health" could contribute to the high probability of low impact factors and citation numbers that also characterize the papers included in "Local Appropriations". Finally, in spite of the authors affiliated in Portuguese organizations having a high probability of assuming the most relevant positions in the publications at stake (i.e., first and last authorships), both the specific type of publications and other associated performance indicators are revealing of a not so developed structure of Portugal's scientific system.

Lastly, we will focus on the specific profile of malaria research that includes 59.1% of all publications (Cluster 3). As suggested by the designation "Global science", this scientific profile is associated with research collaborations throughout the world. In addition, it is also associated with organizational, practices and cultural features previously reported under academic and epistemic capitalism. Some of the features were previously reported in studies focusing on biomedical sciences, including malaria research. To be more specific, our data show that papers in Cluster 3 are associated with an international pattern (Gupta and Balaji, 2011; Hicks and Katz, 1996; Patrício, 2011; Santos Pereira, 1996; Santos Pereira, 2002) and with heterogeneous actors (Godin and Gingras, 2000; Hicks and Katz, 1996), including the industry. Since no associations were found with civil society organizations, at this point, we have to conclude that the role of public science in malaria research developed by Portuguese organizations and revealed by indexed scientific publications seems to be minor. In what concerns the industry participation, it always took place through public-private partnerships, a feature that is revealing of the development of market-like activities by academic institutions, as described under academic capitalism (Slaughter and Leslie, 1999; Slaughter and Rhoades, 2004). These cooperative efforts confirm the current patterns of R&D developed by pharmaceutical companies (Daems et al., 2014; Rafols et al., 2014). In addition, particularly considering that malaria distribution is spatially limited, and mainly affects very poor regions and populations, it was not to be expected that malaria research would be a major target for pharmaceutical and biotechnological companies. Two lines of reasoning can be put forward for the small but significant participation of industry in these studies. On the one hand, the increasing global travelling expose people who can afford medical treatment to diseases to which they would not be otherwise exposed to (Cullen et al., 2016). On the other hand, the spatial limitation of malaria distribution and its seasonal activity are impacted upon climate factors; local capacity to control the disease; and other socio-economic factors such as the level of land use, urbanization, population growth, and mobility (including human; mosquito vector - *Anopheles*; and parasite - *Plasmodium*). This being the case, if today we have almost half of the world population already at risk of developing malaria (World Health Organization, 2016), the 21st century could witness further increases (Caminade et al., 2014). This scenario can create new market opportunities that are being anticipated by industrial actors.

Very much related to what we have been discussing is that this "Global science" profile groups papers that, methodologically speaking, are associated with either translational research practices (the closest level to an applied model of research), or practices that mobilize cellular and animal models of research (the second closest level). These methodological designs reveal a proximity to an applied model of research that has been shown to be more prevalent in more recent times (Hicks and Katz, 1996) and to characterize research performed within academic capitalism. This was not previously studied in the context of malaria research.

Finally, we analysed performance indicators that were suggested to be increasingly relevant for researchers' careers and that could reveal the presence of more pervasive capitalist dynamics, as described under epistemic capitalism (Fochler, 2016). Since most recent malaria research is associated with top cited papers (despite the lower amount of time that these publications had to be cited), one can infer the increasing importance of performance for research in malaria. One additional feature is further revealing of the dependence of Portuguese science on the countries with a longer institutionalized scientific system: the dependence position of Portugal's affiliated researchers (generally assuming middle positions in authorships) on these publications. These features were not previously addressed in biomedical research including malaria research.

We are thus in the presence of three research profiles that range from a "Beginners" stage, in which authors reviewed others work, to a profile that maximizes on Portugal's links to its former territories where malaria is still endemic, to a more recent profile where fully legitimatized empirical studies are developed, but in which Portugal assumes a secondary role.

Taken together, both "Global science" and "Local appropriations" profiles are characterized by features that have been associated with academic and epistemic capitalism. While public-private partnerships reveal the presence of market-like activities, a crucial feature of academic capitalism, the production, attribution, and accumulation of non-monetary forms of capital, a central characteristic of epistemic capitalism, is shown by the authors' positioning and differential impacts of published indexed research. As such, our data allowed us to establish the presence of features of both academic and epistemic capitalism. Nevertheless, the relative importance of these features to the actors that develop malaria research can not be inferred from the present study and would require the application of a diverse methodological approach. This would involve for instance, interviews to the authors of these studies. Only then, could we assess, as Fochler (2016), the actors perceptions on the influence of these diverse forms of capital in knowledge production.

Altogether, our data suggest that Portuguese malaria research follows dominant modes of production present countries with more developed S&T systems and imposes these modes in countries with less developed S&T systems, such as former Portuguese territories.

### *Limitations and opportunities for future research*

One first limitation of this study results from the use of the platform *Web of Science*, and its associated bibliometric indicators. This type of data bank and indicators are understood, within the biomedical community, as important tools for the assessment of scientific practices (Adam, 2002; Saha et al., 2003) or as reliable sources of scientific legitimization, with high impact factors and citations allowing for future success in applications for grants and jobs (Rushforth and de Rijcke, 2015). However, their known insufficiencies and bias impose some limitations that require further discussion. As previously said, journals' impact factors measure the average number of citations of papers published in a specific journal in a specific year. As such, they do not specifically mirror the impact of any specific paper. Actually, it has been previously reported that journals' impact factors are mostly determined by citations received by a small portion of all publications (10-30%) (Slegen, 1997). In fact, our data reflect this bias – while publications in the "Beginners" profile are associated with high impact factors, the number of citations for the specific publications in our sample are low. Another concern regarding the use of the so-called performance indicators relates to the use of citations counts as a direct measure of the relevance of a specific paper. However, acknowledging the influence of a particular paper is one among many reasons a paper is cited. Authors cite others' work to refer to a specific methodology or work within the same thematic focus; to support a specific idea developed in their work; to acknowledge the work of their mentors or leaders in the field; or even to rebut others methods, results or conclusions. As such, citations counts *per se* are not indicative of research influence but rather indicate a paper's usefulness for writing other papers (Belter, 2015). Therefore, citation-based indicators only allow for a partial evaluation of scientific practices (Gläser and Laudel, 2007; Weingart, 2010). A further caution note to state that impact factors and number of citations are very much dependent on the journal's area(s) of research. This means that an high impact factor in social sciences (such as an impact factor of 2) would be considered to be a relatively low impact factor in biomedicine (an area of research where top journals, such as Science, Nature or Cell, have impact factors above 20). Considering that 1) most journals included in our corpus of analysis belong to more than one Web of Science research area and category, and 2) the above-mentioned limitations of performance indicators, we did not mobilize impact factors or citation numbers to characterize performance *per se*. Rather, we complemented these quantitative performance indicators with other bibliometric indicators and qualitative indicators resulting from the content analysis of the full publications. As such, our aim was to characterize performance patterns in what it relates to other characteristics of malaria research profiles. This being said, a deeper understanding of these patterns would require a more comprehensive qualitative analysis of the papers that cite the original work to understand the context and terms in which the reported citations occur. Even though we do recognize the limitations of this platform and of its bibliometric indicators, and, additionally, that by using it, we are legitimizing the quantitative outputs it produces, we did not mobilize these indicators as crude measures of research performance. Rather, these were mobilized in combination with other indicators of scientific practices that result from content analysis of the papers in our sample. Despite the above-mentioned limitations, this approach allowed for the development of a first broad characterization of malaria research in Portugal, including some inputs on what is perceived by the scientific actors working on malaria to be significant or useful malaria research.

Another concern still arises from the usage of *Web of Science*. This type of database is today understood, within the biomedical community, as an important tool of analysis of scientific practices (Saha et al., 2003). However, that does not seem to be the case for publications arising from Portuguese organizations in the beginning of the twentieth century. At that time, malaria research developed in Portugal was rather published in non-indexed scientific *fora* (Ferreira, 2016). If the analysis now developed give us some relevant inputs as to the internationalization of peer-recognized research developed in Portuguese organizations since the beginning of the 20th century, it does not integrate all malaria research performed within these organizations. Only an analysis that addresses non-indexed scientific publications could reveal a more complete scenario of malaria research in Portugal.

A third limitation of this study relates to the fact that we are focusing on research on one particular pathology, i.e., malaria, a disease that presents a number of specificities (short term infectious disease, mainly affecting poor countries and populations, and thus, not particularly attractive for industry's investments) (Daems et al., 2014; World Health Organization, 2016). This implies, from the go-ahead, that some of the patterns of today's science, such as the industry's participation, might not be so prevalent in our sample. In any case, we were still able to show their small but significant presence in the most recent publications (Global science). In addition, one should keep in mind that in spite of the mobilized methodology being able to capture some connections between science's actors, it does not exhaust all concrete interactions that, in the case of public-private partnerships, can include the funding of projects; patents; financing of teams; departments; or research institutions (Krimsky and Nader, 2004). The same limitation can be pointed out as for the analysis of public science, which has been described to take other forms of collaboration and action that are precluded from scientific publications (see Moore et al., 2011 for a review). These interactions will be addressed in a future project mobilizing a qualitative analysis that thoroughly characterizes the scientific process, the actors participating in it, and their positions throughout research development.

A fourth limitation to be pointed out regards the characterization of the methodology of the different articles. If our approach has allowed to directly address whether an application dynamics is present in malaria research, it does not detail for instance, within translational research, the specific subgroups of malaria treatments that could be at stake. Such a categorization is highly relevant for establishing a research agenda to eradicate malaria, and has been previously proposed by Alonso and colleagues (Alonso et al., 2011). Future studies on malaria translational research should mobilize it.

Finally, the fact that we have chosen to focus on malaria research performed within Portuguese organizations means that we are in face of a case study. If this approach allowed us, on the one hand, to assess the full universe of publications, giving access to extremely valuable information, on the other, it does not allow us to address these contributions in a broader context, a study that remains to be done. It does give us, however, import hints into the potential features of malaria research in general and of biomedical research in Portugal. Future studies should cover both suggested directions, studying malaria research in a broader international context (assessing whether similar research profiles are also present), and addressing other pathologies in the Portuguese context (checking whether the contextual specificities now revealed are also present in the research patterns of other pathologies). These contingencies, though situating our study, do not jeopardize the social and scientific relevance of this research, in which we will now focus.

## *Concluding remarks*

This study revealed the main dimensions of malaria research. These involve, at a first level, the actors that actively participated in the publication effort. Along this dimension of our plane, we can observe transformations at the organizational level. The second dimension reflects the types, methodological approaches, and performance levels of the analysed publications. As such, this dimension gives us the transformations of scientific practices and culture. Altogether, our results show that the dimension characterizing who is developing malaria research has a higher explanatory power of the structure of the scientific landscape, than the dimension addressing the practices that are being developed and their underlying culture. As such, the present study suggests that malaria research is indeed the result of on-going struggles, coalitions, and repositioning of academic, corporate, governmental, and civil society actors.

Our results further show that the most recent profile of malaria research in Portugal is associated with international and heterogeneous actors (including associations with industrial but not civil society actors), and application- and performance-driven research. Since this profile is consistent with the theoretical backgrounds of academic and epistemic capitalism, it suggests that despite pressures to pluralize science, even non-profit driven research profiles are framed by the dominant modes of organizing, modes of doing, and modes of thinking. In these settings, Portugal seems to be embodying the scientific modes of production from countries with more developed S&T systems and reinforcing them, by imposing some of its features in former Portuguese territories.

Finally, the mobilized methodology allowed establishing three profiles that portray the recent evolution of the Portuguese scientific system and the implemented policies and measures. This being the case, we suggest that this approach can be used as a tool to assess the latest trends of the scientific market and, particularly, of biomedical research.

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## Notes

1. Postal address: Avenida de Berna, 26 C, 1069-061, Lisboa, Portugal.
2. To the best of our knowledge, this is the most recent data addressing the prevalence of malaria research within all biomedical studies.
3. Stokes developed a quadrant model of scientific research in which basic and applied research are not opposite modes of research but rather modes with different goals. According to this model, "Basic research" (Bohr's quadrant) aims to deepen the understanding of particular phenomena or processes without considering knowledge's potential application. "Applied research" (Edison's quadrant) is uniquely guided by applied goals while "Use-inspired research" (Pasteur's quadrant) includes all research that aiming for further understanding of phenomena or processes, is inspired by its potential applications. The last quadrant includes research that is driven by researchers' curiosity on specific phenomena or processes, neither aiming for a general understanding (Bohr's quadrant), nor application (Edison's quadrant).
4. Quite illustrative of this point is the study of Hicks and Katz focusing on United Kingdom publications in all scientific fields between 1981 and 1991. In this study, the authors addressed the "application of science" through the analysis of variations in the number of publications 1) from organizational types that are closer to an applied model of research (such as hospitals and industry) and those that are not, and 2) in fields of science closer (including medicine) and further from application. While, in the first case, the authors report an increase in applied research, the same trend is absent in the analysis of all fields of science. Still, medicine is the fastest growing field of science.

5. The impact factor refers to the average number of citations *per* paper published in a specific journal (i.e., it divides the total number of citations of all papers published in a journal on a specific year by the total number of papers published in the same journal during the two preceding years). Thus, impact factors are not specific to the paper being analysed. On the contrary, the number of citations specifically reveals how many times a specific paper was cited. In both cases the citations are counted within a specific database of scientific journals (e.g., Web of science; Scopus).
6. A discussion on the limitations of impact factors and number of citations can be found in the section "Limitations and opportunities for future research".
7. This study is focused on publications between 1988 and 2009 with Indian organizations.
8. Malaria is triggered by the bite of a female *Anopholes* mosquito leading to the passage of the parasite *Plasmodium* into the host's bloodstream (Ferreira, 2011).
9. The hierarchical cluster analysis used the squared Euclidean distance as the measure of similarity between the subjects (i.e., indexed malaria papers). Several clustering methods were tested and the increase of the agglomeration coefficients suggested the presence of three clusters. For the same number of clusters a 66% to 100% degree of convergence between tested clustering methods was found (Within-groups Average linkage; Between-groups Average linkage; Single linkage; Complete linkage; Centroid linkage; Median linkage; and Ward linkage). The final cluster membership of each subject was performed with the non-hierarchical method k-Means (Marôco, 2014) and then analysed in relation to the original variables in order to proceed to the cluster characterization.
10. Adjusted standardized residual>1.96; 95% confidence level: $|Z|>1.96$.
11. Adjusted standardized residual=1.9; 90% confidence level: $|Z|>1.645$.

# Appendix 1

**Supplementary Table 1.** Contributions of the categories to the inertia of the dimensions and centroid coordinates of the considered variables' categories.

| | | Contribution of the category to the inertia of the dimension | | Centroid Coordinates | |
|---|---|---|---|---|---|
| | | Dim. 1 | Dim. 2 | Dim. 1 | Dim. 2 |
| Number of authors | 1 | **0,032*** | 0,021 | -1,977 | 1,259 |
| | 2-4 | **0,050*** | **0,023**** | -0,853 | 0,448 |
| | 5-9 | 0,001 | **0,031*** | 0,097 | -0,386 |
| | 10 or more | **0,053*** | 0,002 | 0,868 | 0,114 |
| First authorship: Portuguese | Yes | **0,032*** | 0,004 | -0,412 | -0,115 |
| | No | **0,065*** | 0,008 | 0,853 | 0,238 |
| Last authorship: Portuguese | Yes | **0,034*** | 0,008 | -0,447 | -0,173 |
| | No | **0,056*** | 0,014 | 0,739 | 0,285 |
| Methodology | Translational | 0,007 | **0,057*** | 0,234 | -0,532 |
| | Cellular & animal models | 0,000 | 0,001 | 0,060 | -0,072 |
| | No live models | 0,000 | 0,000 | -0,505 | 0,096 |
| | Non-experimental | **0,035*** | **0,246*** | -0,991 | 2,040 |
| Paper type | Research articles | 0,012 | 0,022 | 0,246 | -0,255 |
| | Reviews/discussions | 0,020 | **0,174*** | -0,971 | 2,231 |
| | Meeting abstracts | 0,011 | **0,030*** | -0,601 | -0,760 |
| | Others | 0,007 | **0,066*** | -0,595 | 1,437 |
| Number of types of organizational affiliation | 1 | **0,039*** | 0,001 | -0,529 | 0,051 |
| | 2 | **0,023**** | 0,000 | 0,457 | -0,038 |
| | 3 or more | **0,021**** | 0,001 | 0,908 | -0,133 |
| Country of Affiliation | Portugal | **0,136*** | 0,002 | -1,442 | -0,141 |
| | International | **0,042*** | 0,001 | 0,446 | 0,042 |
| Collaboration with former Portuguese territories | Yes | 0,003 | **0,073*** | 0,217 | -0,883 |
| | No | 0,001 | 0,019 | -0,061 | 0,230 |
| Collaboration with Europe, North America and Oceania | Yes | **0,055*** | 0,017 | 0,561 | 0,246 |
| | No | **0,098*** | **0,031*** | -0,989 | -0,433 |
| Collaboration with countries with endemic malaria and not former Portuguese territories | Yes | **0,052*** | 0,006 | 0,963 | 0,264 |
| | No | 0,014 | 0,002 | -0,250 | -0,069 |
| Publication subject area | Infect diseases/Trop Med | 0,002 | 0,001 | 0,113 | -0,070 |
| | Multidisciplinary | 0,002 | 0,006 | 0,202 | 0,306 |
| | Mol & Cell Biol/Immunol | 0,000 | 0,002 | 0,096 | 0,215 |
| | (Bio)chem/Pharm/Biotech | 0,000 | 0,002 | -0,047 | 0,193 |
| | Medicine and Public Health | **0,023**** | 0,012 | -1,182 | -0,658 |
| | Others | 0,006 | 0,000 | -0,808 | -0,155 |
| Impact Factor | Under 2 | 0,014 | 0,019 | -0,539 | -0,498 |
| | Between 2 and 10 | 0,007 | 0,000 | 0,180 | 0,016 |
| | Above 10 | 0,000 | **0,060*** | -0,101 | 1,517 |

**Supplementary Table 1 cont.**

| | | Contribution of the category to the inertia of the dimension | | Centroid Coordinates | |
|---|---|---|---|---|---|
| | | Dim. 1 | Dim. 2 | Dim. 1 | Dim. 2 |
| Citations | Top 10% (most cited) | 0,008 | **0,025*** | 0,560 | 0,750 |
| | ]10-25%] | 0,006 | 0,003 | 0,369 | 0,205 |
| | ]25-50%] | 0,009 | 0,000 | 0,367 | 0,016 |
| | ]50-100%] (least cited) | **0,023**** | 0,011 | -0,406 | -0,215 |

Note: Dim.: Dimension Infect diseases/Trop Med: Infectious diseases and Tropical Medicine; Mol & Cell Biol/Immunol: Molecular and Cellular Biology and Immunology; (Bio)chem/Pharm/Biotech: Biochemistry; Chemistry, Pharmacology; and Biotechnology.

The contribution of the category to the inertia of the dimension represents the amount of a dimension's inertia (variance) that is explained by a point (category). One should privilege the categories that have an above average contribution: since the sum of the contributions of all categories in each dimension equals 1, the reference cut point is given by 1/p (where p is the total number of active categories). In this case, the cut point is 0.025 (=1/40). Therefore, the categories with a contribution above 0.025 are the ones, for each dimension, that produce higher discrimination between the objects. * represents categories with an above the average contribution to the inertia of the dimension; ** represents categories with a very close to the average contribution to the inertia of the dimension.

The centroid coordinates depict the position of each category in the perceptual map, aiding its interpretation and visualisation of the found profiles. Since not all categories have a significant discriminant contribution, one should only consider the projection of those that have an above average contribution (or close to the average). This is why those categories with smaller contributions are represented as hollow circles with no labels and those with significant contributions are represented as filled circles with labels (see Figure 2).

## Vincenzo Pavone and Joanna Goven (eds) (2017) *Bioeconomies: Life, Technology, and Capital in the 21st Century.* Cham : Palgrave Macmillan. 350 pages. ISBN 978-3-319-55650-5

*Eduard Aibar*

*eaibar@uoc.edu*

Biomedical sciences and biotechnologies are one of the most important areas of contemporary science. Not only are they producing the biggest share of global scientific publications but, since the beginning of this century, they have become the main destination of public funds for R&D in many countries (NSF, 2018). But besides scientific outputs and funding allocation, some authors see them as representing the vanguard of a new historical regime in the social organization of science: the *globalized privatization regime*, born in the 80's and characterized by a new constellation of links between science, the state, and industry (Mirowski, 2011).

Vincenzo Pavone and Joanna Goven's edited volume focuses on present biomedical sciences and biotechnologies through the lens of *bioeconomy*: a notion that has become a large umbrella under which many different phenomena, practices, projects and technologies are usually grouped, often in a rather confusing and heterogeneous way, but which seems to be leading public policies, institutional developments and broad visions of the future across the world with the promise of linking *economic growth*, *global competitiveness* and *health improvement* in new and disruptive ways. In fact, much of the work presented in the book is intended to disentangling the tensions, contradictions and conflicts involved in that very notion - which the editors use in plural (bioeconomies) in order to stress its diverse coinages and meanings - while confronting promises and policy expectations with actual developments in particular initiatives and projects.

In the best STS tradition, the book is a canonical instance of deep theoretical work based on rich and systematic empirical research. All chapters analyze - using different standard qualitative methods - and discuss in great detail specific case studies, ranging from particular technologies, initiatives and projects, to the specific sites, institutions and contexts where they are developed or put to work. Regenerative medicine, reprogenetics, surrogacy, genetically-modified soy, red blood cells manufacturing, egg donation, research on the collective microbiome and different forms of biobanking are among the specific techniques and areas explored, always through particular projects and initiatives. Though most case studies concentrate in European and US experiences, there are some chapters presenting empirical analysis in other parts of the globe: from Singapore and India, to Argentine and Australia. The initiatives analysed range from broad and generously funded supranational projects like IMI (the *Innovative Medicines Initiative*, the world's largest public-private partnership in the life sciences, launched by the European Commission in 2008) to very specific R&D projects of a smaller scale and more limited ambitions.

The book is structured in four sections. The first one deals with *institutional* transformations and explores the way bioeconomies are already changing the roles and responsibilities of the state, scientific research and institutions and citizens. The second section addresses the question of *value* - a much discussed issue in previous scholarship on biotechnologies - and includes works investigating how different kinds of value - without restricting to the economic - are generated, appropriated and distributed in bioeconomy projects. The third one focuses on conflicts and resistance, while the fourth analyzes the interplay of structural inequalities and altruistic acts in areas such as assisted reproduction, stem cells, pharmaceutical development and cultured red blood cells.

The book's basic argument, explicitly stated in most chapters, is that the bioeconomy is not simply a neutral, interest-free economic project but the "core axis of a full-fledged *political* project" with a clear neoliberal orientation (p. 94). It is already apparent that biosciences and biotechnologies have been increasingly intertwined with the power of capital and with modes of governance during the last decades. But the new general framework of bioeconomy is fostering policies that encourage the commercialization of science, giving public support for private commercial actors and adapting existing regulations to the needs of innovators and commercializers. While in the liberal frame the state has only got a residual role in compensating for market failures, in the neoliberal landscape the state is granted a key role in reshaping old markets and creating new ones. Neoliberalism is not only about privatizing but mainly about actively extending the market logic to all sorts of new social realms, a task for which governments and policy measures are constantly being mobilized.

Many of the bioeconomy initiatives and projects analysed in the book share a similar pattern of interaction between government, industrial corporations and scientific research. Basically, the state is required to fund the early stages of new therapies and health products - where failure is common and risks and costs are high - and, eventually, must purchase them - if they prove to be successful - through their public health systems (p. 30). Under this supply-side neoliberal approach, bioeconomy projects end up socializing risk and privatizing benefits. For that purpose, a double identification is previously performed: public interest is equated to innovation and innovation itself is interpreted as entailing the commercialization of products. In this active role as innovation facilitator, the state must remove regulatory barriers - in many instances limiting governance to preserving the safety of new therapies or medicines - and promote public acceptance of biotechnology. Interestingly, and autonomous view is science is often instrumentalized in order to turn social contestation as irrelevant. The political authority of scientific expertise is used to overcome social dissent in the name of government responsibilities (p. 62).

Most of the chapters in this volume provide specific examples of this general strategy behind bioeconomies, while analyzing the different ways in which it is enacted and identifying intended and unintended implications for particular collectives and social groups: from migration policies to new forms of gendered and racial discrimination in assisted reproduction. If bioeconomy is supposed to improve both "wealth and health" the authors of this volume ask themselves whose wealth and health is really involved, and who is left out.

The different pieces of work rely, sometimes simultaneously, on standard middle-range STS analytical approaches - from co-production and sociotechnical imaginaries, to social contract theory and feminist approaches - and on a more political economy framework. Though this pluralistic - almost binary - theoretical stance is not necessarily a drawback, some readers might expect a more explicit discussion of the possible tensions between these two areas of scholarship. In that line chapter 12 provided and interesting confrontation between the two different ways in which patients' participation is conceptualized in both paradigms. Fortunately, the final concluding chapter does a very useful wrap-up task for the reader, synthesising the most important arguments deployed along the volume, linking the different topics that have shown up and suggesting lines and questions for future research.

The volume is indeed an excellent piece of solid academic work. It is certainly of much interest for STS scholars in general, but more specifically for those working on present biomedical sciences and biotechnologies. It could also be very useful and inspiring for scholars from related fields like political science, public administration, management and economics, interested in health policies and current changes in the health system. Finally, practitioners - from biomedical researchers to health professionals - and patients and people involved as subjects or objects of biotechnological developments, could also benefit a lot from its reading.

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# John Law and Evelyn Ruppert (eds) (2016) *Modes of Knowing: Resources from the Baroque.* Manchester: Mattering Press. 265 pages. ISBN: 978-0-9931449-8-1

*Sarah Pilar Iacobucci*
*sarahiac@ucm.es*

Theatricality. Boundlessness. Heterogeneity. Folding: both one and two. Distribution, movement and self-consciousness. Mediation. These are the techniques of baroque art that one of the editors of *Modes of Knowing: Resources from the Baroque*, John Law, lists in the introduction as amongst those which make the qualities of otherness, emotion, and embodiment (p. 29) so crucial to baroque modes of knowing and doing. The book sets off from the widely discussed point that the ways in which we know the world are not given, but are part of distinct political, social, and historical constellations, and ways of doing the world. Focusing on our conventional ways of knowing as social scientists, Law compiles a list of those things which we often "bracket, forget, and conceal" (p. 19) in our interpretation and representations: passion, bodies, material heterogeneity, excess, specificity, formlessness, performativity (p. 19-20). STS and other fields have identified and attempted to tackle these lacks in various ways, but in this book we are presented with the baroque as a possible way of knowing and doing that provides an exciting way to engage with these qualities that have been othered from academia for so long. As Law states in the introduction, the baroque "knew extravagantly and excessively" and "knew itself to be performative" (p. 23), among other characteristics. Thus, given that many of the qualities of this way of knowing have been long espoused as alternatives throughout STS and other fields, the baroque is presented as "a storehouse of possible alternative techniques" (p. 23).

For a reader who might be numbed by many of the academic constraints they find themselves shackled within when doing their work, the way in which the baroque seems to provide a way out of so many of these constraints is incredibly interesting. The book is an edited volume of contributions made by participants of the workshop 'The Baroque as Empirical Sensibility'. It divides itself into two halves. The first half groups those essays which reflect upon qualities of the baroque by using them to interpret their research, while the second half is intended to encompass those chapters that experiment with performing a baroque way of knowing.

Blaser's chapter in Part I, along with other parts of the book, deals with parts of the baroque's notorious history of being a technique of dominating religious or colonised subjects, addressing doubts that could make many a reader wary of adopting this perspective and way of doing. "A baroque sensibility is neither dominatory nor transgressive. Which of these forms it takes depends on specifically situated relations" (p. 60). Using community participatory workshops in the Yshiro Indigenous community in Paraguay, Blaser demonstrates how excess is produced and used in, on the one hand, the development community, where it comes about from their *horror ignotum* (horror of the unknown) of indigenous visions and ways of life, and on the other hand, from the indigenous standpoint, where it comes to be other ways of knowing and doing. By making evident the destructive qualities of desperate attempts to know, to fight *horror ignotum*, Blaser proposes a very interesting question for those considering a baroque mode of knowing in general: "might it actually just end up adding more techniques to escape the ghost of *horror ignotum*?" (p. 81). Much of the book is occupied with a baroque mode of knowing's transgressive qualities, but a possible critique that could be made of it is not reflecting enough on how it could slip into a dominating role, as hinted at in Blaser's question.

To be fair, however, this is addressed in a way in another one of the book's outstanding contributions by Mattijs van de Port. Van de Port grapples with the question of how to bring the feeling of being lost in what he calls "the rest-of-what-is", or Lacan's real, the whole of the hole, without domesticating or making these experiences graspable. Speaking about how the Church, in baroque art, tried to "'colonise' the experiences of the ineffable" (p. 181), he calls upon us to be careful to not do the same by replacing this colonising role with that of the authority of academy, which might try to explain away these experiences. Thus, I see here another way in which the book cautions the reader into what could be slippages away from the baroque's possible transgressiveness.

One of the most important themes I found in the book, which were included in van de Port's chapter, Evelyn Ruppert's wonderful chapter, and several others, was that of how the baroque can be a way of doing that plays with the performativity of one's works. As Law notes in the introduction, "we rarely set out to write texts intended to induce ecstasy-or loss of self in any form-in the reader… the knowing subject is much more self-contained" (p. 26). In explaining her proposed sensory sociology, which shares much in common with a baroque perspective, Ruppert speaks about how this type of sociology recognizes the performative and inventive qualities of social research, that they are "not innocent but political" (p. 146). This political aspect is very important to keep in mind when we think about what we want our social research in general to do. By showing how the (x)trees project by the Mexican artist Agnes Chavez enacts data visualization in a very different way to most social researchers, so as to provoke an "immersive and embodied" experience (p. 154) where "excess is not contained but flows" (p. 156) Ruppert shows how this brings about an "active, contemplative, and engaged subject" (p. 157). Using baroque qualities to bring about this type of subject or experience is also seen in van de Port's chapter as he concludes with the idea that visual art could be used in conjunction with our research to help them experience the ineffable, and identify more with whatever subjects our research may be about and "a greater commitment to find ways to relieve their plight" (p. 192). Given that one could presume that most researchers in STS wish to make some difference in the world with their research, these discussions seem very important. Another chapter that highlights this performativity is that of Helen Verran and Brit Ross Winthereik in which they question what different diagrams can do.

Another interesting theme which was touched upon throughout the book were the artifacts and aesthetics that form part of the institutions of knowing in academia that keep the othered qualities of the baroque out. These ranged from the effects and things different diagrams might do, to the feelings of constraint produced when trying to explain unspeakable emotions in a "vacuum-cleaned conference room, full of spotless white Fornica tables" (van de Port p. 168), to formal academic writing conventions. As Law makes clear in the introduction, these constraints are embedded in certain institutional histories and material conditions, but it might have been interesting if the book had included a chapter or some thoughts on how academic institutions or gatherings could change to foster more baroque ways of knowing and doing: the material conditions that could foster these reflections more.

Annemarie Mol's chapter, the last in the book, which aims to explore baroque coherence, is another one of the highlights of the collection. It finishes off the book quite nicely, because within all the characteristic baroque chaos: no inside, no outside, who is what, no center, etc, in which we might get lost and think anything goes, she uses the clafoutis to show that, while this is a particularly good symbol of the precariousness of the baroque as a composition, it "does not mean that anything goes" (p. 258). But what exactly makes a clafoutis a clafoutis is performed constantly and elastic, and not possible to pin down, needing to be *just so*, an idea which escapes our intellectual grasp. A fantastic chapter to tie together the baroque: it does have a coherence, but these are temporary and performative.

In all, I would highly recommend this book to anyone in social research interested in reflecting upon how they do their work, and what their work does in the world.

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