The role of hybrid governing in science: fostering research across boundaries

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ABSTRACT: Many contemporary studies and policy reports describe how translational research in biomedical sciences has been hindered by the different imperatives of the constituent logics of academic science and care. This study shows how hybrid governing softens tensions between competing logics, helping leverage knowledge bases, and span research boundaries in the pursue of translational research agenda. We develop these ideas in a multimethod longitudinal case study of the largest translational research program in England: the Biomedical Research Centers (BRCs) program. Qualitative longitudinal data – gathered from 55 in-depth interviews with scientists, and observations and on-site visits conducted over a six-year period (2007-2013) – highlights how the Department of Health (DH), through hybrid governing practices, has been able to influence scientists' research agenda toward translational research by both *rearranging* and *honoring* scientific commitments. We outline these two specific mechanisms and theoretically elaborate on the hybrid governing concept, which has softened the potential conflict that the juxtaposition of normal disciplinary research and translational research could have created. Quantitative data analysis reveals significant changes in the degree of novelty of the BRC scientists' publications, suggesting that the program has had also noticeable epistemic effects.

Keywords: translational research, hybridity, scientific paradigms, sociology of science, longitudinal study, mix method

Introduction

In recent years, translational research has become a cornerstone of many national health systems. In U.S., the National Institute for Health (NIH) has funded 62 translational centers with a budget of US$500 million per year; the European Commission has allocated a €6 billion budget for health-related research and, in the United Kingdom, the National Institute for Health Research (NIHR) has invested £450 million over five years to foster translational centers. Such a preponderant role has come with the realization that translating basic scientific advances into new drugs, devices, and treatments for patients can potentially help tackle many unmet health and medical needs (cf. Fontanarosa & DeAngelis, 2003; Rosenberg, 2003; Woolf, 2008). Despite these developments, the undertaking of translational research has posed many challenges as it presupposes the involvement of two very distinct logics, the academic science and the care one, into hybrid projects and processes. Moreover, the external governing of such translational efforts adds further strains as it directly collides with the self-governing principle constitutive of basic sciences. Consequently, the governing of translational research pose interesting questions to organizational scholars: How can hybrid governing reduce tensions between logics, leveraging constituents´ knowledge bases? Can hybrid governing produce sustainable epistemic effects at the science level?

To address these questions, we conducted a multimethod longitudinal case study of the inception and evolution of the largest translational research program in UK – namely the comprehensive Biomedical Research Centers (BRCs) – for a period of seven years (2007-2013). Extensive access over a prolonged period of time gave us an unusual opportunity to understand translational research and the conditions that might affect it. Our qualitative data revealed BRCs have introduced new questions and methods into the biomedical research agenda in order to leverage scientific knowledge to drive more novel, multidisciplinary and applied outcomes. Inductive analyses of these data yielded several insights. First, several identified practices were implemented with a view to releasing some aspects of the normative commitments of science and opening new research spaces. Second, and concomitantly, BRCs have *honored* already legitimized and established scientific procedures and customs, in line with the more conservative traits of a normal science (Fleck, 1936, Kuhn 1962).

Our quantitative study of publications by BRC research leaders similarly reveals important changes on research output resulting from BRC membership. In particular we find that BRC leaders reduced the degree of proximity between current and past research projects following the

creation of BRCs. This suggests that BRC membership induces scientists to explore more and undertake research in different research areas as compared to their past activities. Our econometric analysis also revealed that BRC research leaders´ publications increase their novelty over the study period as compared to that of the control scientists. This suggests that BRC membership increases the novelty of the scientific output. All in all, these findings suggest that BRC program has successfully transcend a linear conception of translational science (i.e. from bench to bed) to embrace multiple knowledge bases from different epistemic domains.

Drawing on the Institutional logics research and the Sociology of Science, we conceptually analyzed and anticipated the tensions that the undertaking of translational research might trigger, as the two constituent logics mobilize different goals and means (Miller and French, 2016). We then theoretically advanced the concept of hybrid governing that can help soften such tensions, which was developed and tested in a multimethod longitudinal case study. We found that for the specific case of English translational program, hybrid governing anticipated and reduced such tension by both *rearranging* and *honoring* scientific commitments. At the core of this conceptual characterization lies the assumption that any radical departure from the constellation of shared commitments that scientists bear (Fleck, 1935, 1936; Kuhn, 1977) could clash with the principle of professional autonomy and the image of science as a self-governing system (cf. Allen, 1977). Consequently, by introducing such a hybrid approach (i.e., by intending both to *rearrange* and *honor* established normative commitments), the potential antinomies that the practice of normal science juxtaposed with that of translational research have been softened (cf. Merton, 1973). This is noteworthy, as the undertaking of translational research introduces practical, applied, and multidisciplinary foci into hitherto theoretical, pure, and disciplinary ones. Jointly, these findings have shown that, relying on these dual mechanisms and the purposive ambivalence created, potential inner normative conflicts (cf. Coleman, 1990) have been lessened, facilitating the adoption of translational research agendas. These findings also carry practical and policy-making implications, as they highlight the vital role played by the recognition and integration of established commitments to influence change in close-knit communities, such as scientific cohorts.

Hybridizing governance in anticipation of resistance between logics

Externally driving translational research within well-established scientific communities has the potential of eliciting multiple intractable conflicts both at the level of the involved scientists and that of the organizational constituencies. Insights from research in academic science have shown

how the logic of science and that of care pose different and contested demands (Raynard, 2016, Miller and French, 2016, Lander, 2016, see also Dunn and Jones, 2010). Additionally, the exogenous character of such imposition might create further resistance within the scientific communities, as it violates the cherished Mertonian principle of external autonomy that infuses many normative and practical aspects regulating practices, (inter) actions, and interpretations (cf. Scott and Meyer, 1994, Gyerin, 1983). We review and integrate the research on Institutional Logics and Sociology of Science to analyze the nature of such conflicts, to study the conditions that allow anticipating and potentially addressing the resistances, and to finally introduce the concept of hybrid governing.

Governing science. Institutional scholars, inscribed in a sociological tradition with an original focus on societal level dynamic, sustain that governance – traditionally related to questions of control and coordination – is central to understanding fields (cf. Hining, Logue, Ziestman, *forthcoming*). Governance mechanisms normalize and regularize interactions, providing the necessary stability and boundary conditions that make possible the emergence of a "common meaning system" constitutive of institutional fields (cf. Scott 2014:106). Stability is central in Greenwood and Suddaby's definition of organizational field, understood as "clusters of organizations and occupations whose boundaries, identities and interactions are defined and stabilized by shared institutional logics" (2006:28). Scott also suggests the centrality of governance to understanding fields, advancing that each field is "characterized by a somewhat distinctive governance system" (2014:231). In this vein, the Sociology of Science has long explained how scientific communities sustain autonomy demands from external individuals and institutions while asking internal members for submission by means of a strong network of commitments (Fleck, 1935; Knorr Cetina, 1999; Kuhn, 1962). As for the former, Allen (1977:41) describes the pursuit of autonomy as the foundational norm of scientific communities to the extent that science should "be free to choose its own problems and that the community of colleagues be the only judges of the relative importance of possible areas of investigation". Academic sciences are thus viewed as self-governing systems. Gieryn clearly describes the tension between scientists and external governance: "Once scientists accumulate abundant intellectual authority and convert it to public-supported research programs, a different problem faces the profession: how to retain control over the use of these material resources by keeping science autonomous from controls by government or industry" (1983:789).

Conflict between logics. Greenwood and colleagues advance (2011) that the understanding of the different features that govern field interactions and bind a field together is critical, particularly under institutional complexity. Such complexity might be triggered when fields become contested through the challenge or coexistence of multiple institutional logics (Greenwood et al 2011, Reay and Hinings, 2005, 2009). Yet, the mere coexistence of multiple logics within a field does not necessarily elicits complexity, as the constituent logics can be complementary (Besharov and Smith, 2014). By its very nature, complexity arises when incompatibilities between logics concur, triggering stances (both at the individual and organizational level) where prescription for action and interpretations are contradictories (Smith and Tracey, 2016, Greenwood et al., 2011). These dynamic are particularly analyzed in the health field in Dunn and Jones´ (2010) study on the medical education, where the logics of care and science coevolve in uneasy tension, due to their different knowledge bases and normative prescriptions that create incongruity over the appropriate ways for treating patients. Other studies have also shown how, within the logic of care, persisting tensions between the professional and market logics change the basis of legitimacy and practices, fostering at a time conflict and field level changes (Scott, Ruef, Mendel, & Caronna, 2000, Reay & Hinings, 2005, 2009, Nigam & Ocasio, 2010, Kitchener, 2002). Specifically for translational research, Miller and French (2016) have argued that the imperative of healthcare and science mobilize very distinct goals and means, finding these tensions at the policy, organizational, and individual level. Together, these studies suggest that the complexity of amalgamating two logics (academic science and care) into the undertaking of translational research is rooted in the different underlying goals and means, as set of principles, that provide guidelines to interpret, act and interact in social situations (Friendland and Alford, 1991). Such differences have been also explicitly recognized in healthcare policy across several countries, such as US, Canada, and UK, where special emphasis has been placed on identifying the barriers that hinder such translational efforts (e.g. DH, 2006, 2009a, 2009d). Specifically in England, the Cooksey´s report (2006) has described the persistent gaps in translational research, identifying differences in cultures, institutional infrastructures and incentives as the main reasons. However, echoing Greenwood and colleagues (2011), field maturity and stability need to be consider when analyzing institutional complexity. Even though translational efforts occupy an interstitial space, the two constituent fields (academic science and care) are more settled logics, and as such, conflict between them are more predictable. Greenwood and colleagues (2011:335) theorize that even mature fields comprised of multiple logics can be stable so long as the relationship between logics is well understood and predictable. Consequently, differences between rival and divergent logics

can be manage, and resistances of individual actors anticipated, as found by Reay and Hinings (2009) for the Alberta healthcare case.

Anticipating conflict. Hence, in more stable albeit complex fields, tensions within and between logics can be understood and the more salient pressures anticipate and govern (cf. Smith and Tracey, 2016). Values, norms and obligations that dictate the appropriateness of interpretations and (inter) actions (March, 1991) evolve in historical patterns and as a result of socially constructed process within each field (Thornton, Ocasio, Lounsbury, 2012:2). Together, stability, historicity, and the social constructed nature of logics allows anticipation and recognition of salient patterns. In particular, scientific communities has been depicted as close-knit groups, in which the adherence to rules and codes of conduct is instilled initially through formal education. Formal education ensures socialization and training, acquisition of scientific skills and standards, and the command of a set of theoretical principles (Scott, 1982). These commitments are further reinforced via scientific practice. The collective nature of this practice strengthens a loosely yet strong network of commitments that encompasses not only conceptual and theoretical tenets but also instrumental and methodological commitments (Kuhn, 1962). The description of scientific communities as thought collectives (Fleck, 1935) helps us gain a more precise understanding of the extent of scientific commitments and their "inherent tenacity". Thought collectives can be construed as communities of people engaged in a certain activity domain who have a shared understanding of that field. Accordingly, collectives' members adopt common ways of perceiving and thinking:

> A truly isolated investigator is impossible (…). An isolated investigator without bias and tradition, without forces of mental society acting upon him, and without the effect of the evolution of that society, would be blind and thoughtless. Thinking is a collective activity (…). (Fleck, 1935)

Furthermore, such a collective way to perceive and think substantiates a critically distinctive feature of academic sciences: the extensive use of peer evaluation in all the stages of scientific work, going from the original allocation of new funding to new lines of inquiry (grant reviews) to the evaluation of output quality and potential impact (journal reviews) and, eventually, career effects (tenure proceedings). With these collective procedures, every scientific community attempts to ensure the standards and quality of their practices, recognizing and rewarding good work and dismissing poor performance (Langfeldt, 2006; Zuckerman & Merton, 1971). On a deeper level, this makes the overall normative commitments of each scientific community pervasive yet visible.

Hybridizing governance. Nonetheless, the fact that some of the more salient resistances that emerge when mixing academic science and care logics can be anticipated does not implies that conflict is entirely reducible. The wider literature on institutional logics has analyzed different responses / outcomes for settling the strains of competing logics (Greenwood et al., 2011). That includes open conflict, temporary truce that allows "coexistence", "replacement" from one logic to other, decoupling, and logics blending into a "hybrid logic" (Dunn and Jones, 2010, Orton and Weick, 1990, Battilana and Lee, 2014, Besharov and Smith, 2014, Meller and Hollerer, 2010). Most of these outcomes, except for the blending of logics into hybrids, do not offer satisfactory long run arrangements to integrate competing logics. To accomplish the latter, organizations have adopted blended "hybrid" structures that allows individuals from different institutional logics to work together in teams (D´aunno et al 1991), projects, interstice structural spaces, and/or organizations (e.g. Battilana and Dorado 2010, Smets et al 2015, Battilana and Lee, 2014). In this stream of research, hybridization is primarily conceptualized as a structural response to complexity (Smith and Tracey, 2016) that work as integrative devises that facilitate coordination. Consequently, hybridity presupposes direct and stable constitutions from existing elements (Battilana and Lee, 2014:400). At the same time, this body of research has highlighted the problematic nature of hybrids as the convergence of multiple logic demands creates different internal and external challenges (Raynard, 2016). Internally, hybrids face challenges related to identities and legitimacy conflicts (see, e.g., Albert & Whetten, 1985; Glynn, 2000; Golden-Biddle & Rao, 1997; Pratt & Foreman, 2000), while externally they experience tensions when dealing with competing external demands (see, e.g., Greenwood, Raynard, Kodeih, Micelotta, & Lounsbury, 2011; Kraatz & Block, 2008; Pache & Santos, 2013; Smets, Jarzabkowski, Burke, & Spee, 2015; Thornton, Ocasio, & Lounsbury, 2012).

Even though these studies have increased our understanding of the inherent tensions of hybrids as structural responses, as Smith and Tracey note, they have do so from "depicting stablished, fixed hybrid organizations" (2016:7) with the risk of both portraying a limited understanding of the organizational features that sustain hybridization and losing the fluidity of hybrid organizing. In this vein, Battilana and Lee have recently called for studies on hybrid organizing, defined as "as the activities, structures, processes, and meanings by which organizations make sense of and combine aspects of multiple organizational forms" (2014:403). Addressing this call, we identify and analyze hybrid governance mechanisms that allows blending the science and care logics into the undertaking of translational research, providing qualitative and quantitative evidence on the

nature of those practices and mechanism, and the effects of such hybrid governing on academic science. More specifically, we analyze how through the hybrid governing, the demands of the various external constituents (university, hospitals, government) where integrating in different governing practices. We also account for internally-oriented aspects of hybrid governing, by studying the configuration of these concrete practices and activities, and their perceived and actual effects on the scientists´ research.

Research Context: The British Health Research Environment

British health-related sciences have long been recognized for the quality and impact of their scientific breakthroughs –most notably the development of penicillin and the DNA structure discovery. These continuous contributions have resulted in a globally competitive research environment (Cooksey, 2006), best illustrated by 29 Nobel prizes awarded over the past 100 years in the fields of Chemistry, Physiology and Medicine to scientists working in British research institutions. These scientific achievements have been recognized not only by the respective research communities but also by the UK government and policy makers. In particular, the autonomy of scientists to set their own research agenda has been deemed as critical for such a development. This prevailing interpretation was formally articulated in a 1918 report on the structure of Government (HMSO, 1918), which suggested that research decisions should be made autonomously, free from any form of political and administrative interference. This tenet, best known as the "Haldane Principle" , reinforced a "curiosity-led" approach to science, leaving little room for government intervention other than as a source of funding. According to this principle, decisions on all research aspects should be made by scientists with little or no pressure from any external institution.

Despite the productivity of the British health research's curiosity-driven approach, which helped set some of the foundations of molecular biology, developmental biology and genetics, there were calls to re-evaluate the "Haldane Principle" on the basis of three primary arguments. First, with increasing health spending, health research priorities were thought to primarily focus on ways to potentially address unmet health needs in the UK. Second, scientists face a number of disincentives, for example in relation to career progression, to further develop their findings from "curiosity-driven" basic research into clinical applications. Finally, the government –or arms-length institutions thereof– is viewed as having sufficient expertise and resources to become an informed customer of health research, positively influencing the health research agenda. While

never fully adopted, the Rothschild Report, "*A framework for Government Research and Development*" (1971), was the first policy document to re-evaluate the 'Haldane Principle' with a view to building a customer-contractor relationship in research funding. In this context, the review of publicly-funded healthcare research led by Sir David Cooksey (2006) and commissioned by the UK Treasury found that research knowledge in the UK National Health Service (NHS) had been under-utilized in terms of clinical delivery. These findings created further pressure for policy makers to bridge basic scientific endeavor and clinical care via so-called translational research, which was broadly understood as "the application of discoveries generated by laboratory research and preclinical studies to the development of clinical trials and studies in humans" (NCBI, 2013).

The translational research pathway should potentially encompass different levels of interactions along the spectrum going from basic research to clinical delivery (Lord & Trembath, 2007). Moreover, such interactions should not be linear or unidirectional, as both findings from basic and clinical research can produce translational outcomes (Soderquest & Lord, 2010). By analyzing this broad spectrum in the UK, the Cooksey report identified two major gaps in translation. "The first gap arises in the translation of basic and clinical research into ideas and products, and the second relates to introducing those ideas and products into clinical practice" (2006:86). Among the multiple barriers viewed as hindering translation, three can be directly associated with the aforementioned commitments. Firstly, while the influence of peer review is effective to identify high-quality basic research projects, it fails to promote translational and applied health research programs. Secondly, as a result of the incentives put in place by scientific publications, basic research has become more prestigious than application, preventing researchers from further pursuing the findings of curiosity-driven science. Thirdly, career choices also play a key role: "clinical research has had a tendency to be underpowered scientifically and uninstructed by many of the advances in modern biology" (2006:38). In order to address these identified gaps, the National Institute for Health Research (NIHR), England's foremost governmental sponsor of translational and applied research, established and fully funded the translational research program articulated around Comprehensive Biomedical Research Centers (BRCs) in 2007. Every BRC –a partnership between a university and a hospital or group of hospitals– is intended to undertake translational research –construed as the realization of scientific discovery to be delivered to patients for their clinical benefit (Snape, Trembath, & Lord, 2008).

Methods

In this research we used a mixed-methods approach in order to provide rich descriptions of the studied process as well as measure its effect. In particular, we used qualitative data (Study 1) to conceptualize hybrid governing and the actual control and coordination practices enacted to reduce tensions between logics and leverage the scientific knowledge base. We then supplemented these insights with quantitative data (Study 2) to assess the epistemic effects of such hybrid governing in scientific publications between the BRC research leaders and a matched control group of scientists.

Study 1: Qualitative longitudinal data and analysis

Research context. In January 2006, the United Kingdom's Department of Health (DH) launched a new national health research strategy, *Best Research for Best Health* (DH, 2006), laying out its vision for research and development (R&D) over the next five years. To substantiate this vision, one of the key policies introduced in *Best Research for Best Health* was the establishment of England's National Institute for Health Research (NIHR) as well as the creation and funding of biomedical research centers program within 'leading NHS/university partnerships'. That same year, the NIHR invited institutions to apply for BRC status. These policies intended to drive innovation in the prevention, diagnosis and treatment of ill-health, to translate advances in biomedical research into benefits for patients, and to contribute to international competitiveness by promoting excellence.

The actual selection of English BRCs was made by an international scientific panel, drawing on members' own expert judgment and based both on a series of analyses provided to them (such as bibliometric ones) and visits to the sites. The actual procurement process unfolded in three critical stages (for a detailed account see van Leeuwen, Hoorens, and Grant, 1999). First, the DH, through the newly created NIHR, published an invitation to answer a pre-qualifying questionnaire. Second, the NIHR posted an online database with all the publications attributed to NHS/university institutions for them to identify or verify this information. Once the verification process was complete, the scientific panel reviewed the information and invited short-listed partnerships to submit full applications for BRC status. Third, the scientific panel received the full applications and conducted both application analyses —including a bibliometric analysis— and interviews with every proposed BRC director and theme leaders.

In December 2006, the NIHR announced the creation of eleven BRCs –five described as 'Comprehensive' (i.e., encompassing multiple disease/research areas) and six 'Specialist' BRCs (i.e., working on specific research areas). The DH set aside £450m to support the centers over a five-year period, i.e., £100m per year, with 50% funding in the first year. The five comprehensive centers organized themselves with a similar structure (see Table 1 below for a brief description of every BRC). Each BRC was led by a BRC Director who also chaired its Executive Board. All five comprehensive BRCs similarly relied on Steering Committee and on International Advisory Board that periodically reviewed BRC research progress, new bids and budgets submitted by research themes. To support the coordination and management of BRC activities, a management office was created to deal with Human Resources, Finance, Governance, and Information Technology issues as well as other services. Also, research efforts were organized and conducted around research themes (some of them were disease-specific and some, cross-cutting). Each research theme was led by both an academic and a clinician to better represent the two partner institutions at theme level. Finally and at the most disaggregated level, every theme had a number of specific research projects, each headed by a senior researcher and staffed with academic researchers and NHS members (clinicians and nurses mostly), the latter devoting part of their time to research. As shown in Table 1, BRCs' research themes targeted the health challenges faced by the UK and highlighted by the Cooksey Report (2006), such as cancer, mental health, chronic and degenerative disease (including diabetes, asthma, arthritis, and older people's diseases), nutrition, diet and lifestyle (including obesity), cardiovascular diseases (including CHD and stroke), and international health (especially infectious diseases –malaria, TB and HIV/AIDS).

Insert Table 1 about here

Data Collection and Analysis. Fifty-five semi-structured interviews served as one of the primary data sources for this study. BRC scientists (directors, theme leaders, and project leaders) and managers from the five BRCs were interviewed over a six-year period. NIHR officials responsible for this program were also interviewed. The interview protocol used was guided by our research questions and based on exploratory work insights. It was administered through a semi-structured questionnaire, with special attention paid to elaborating the specific characteristics of each case study as a starting point for theory-elaboration. All the interviews were taped and transcribed, leading to a total of 685 pages of interview transcripts available for analysis. For this study, we also conducted visits to the sites and non-participative observations of several meetings at BRCs facilities, including theme leaders' meetings, BRC Managers' meetings, public engagement

meetings, etc. Overall, ten meetings were observed. Finally, we supplemented informants' interviewing and non-participative meeting observation by gathering archival data, collecting both proprietary and public documents. For the former, we had access to minutes of meetings, yearly business and research plans, budgets, supporting documents, financial reports, and auditing reports. In the case of publicly available data, we analyzed formal policies, public reports, web pages, and external communications related to the BRCs (Table 2 below describes case informant data).

Insert Table 2 about here

We primarily based our analysis on the iterative qualitative methods proposed by Miles and Huberman (1994), although we did take some recommendations from Glaser and Strauss (1967) on comparative analysis, and Rubin and Rubin (1995) on interview analysis. Following multiple stages of inductive examination of BRC structure, evolution, and practices, we analyzed the nature and characteristics of each BRC and their impact on scientific practices. To begin the analysis, we initially developed a provisional list of codes (Miles and Huberman, 1994) consisting of themes drawn from the literature reviewed and recurrent concepts grounded on the data of the five BRCs. A coding protocol, in the form of a list of structured codes, was developed in order to analyze the data. At this point, two of the authors independently coded four complete interviews so as to assess the reliability of this categorization scheme. We specifically checked for inter-coder reliability (Cohen's kappa= 0.82) (cf. Lombard, Snyder-Duch, & Bracken, 2002), and we discussed the differences for the coding that lacked agreement. Then, we proceeded to code the other transcripts. To this end, we used NVIVO qualitative analysis software. Table 3 shows the analytical stages followed and corresponding outputs.

Insert Table 3 about here

Results for study 1: qualitative data. Our inductive analysis of the inception, evolution, and impact of the NIHR BRC program on scientific practice in 2007-2013 has revealed two main theoretical dimensions that introduce both change and stability into the matrix of commitment in biomedical science. The first dimension proposes a dynamic of change to the extent that, through a number of different practices, it intends to *rearrange commitment* with a view to releasing some aspect of normal science. The second identified dimension, in line with the more conservative

aspects of a normal science, aims to *honor* already legitimized and established scientific processes and practices. Such hybrid approach is coherent, as the DH's overall intention regarding translational research was to introduce new questions and novel methods to tackle the UK's health priority in already established scientific fields, leveraging the existing science base. Based on this evidence, we will next summarize the main findings for each dimension and the practices that have supported them.

***Rearranging Commitments*.** The NIHR's intent in launching BRCs was not a radical or revisionary departure from well-established English scientific practices. Rather, this initiative was meant to influence the research agenda in order to address the UK's health and delivery challenges. To that end, every BRC had to incorporate a structure and a set of governance practices that could potentially release the normative grip of academic institutions. Perhaps the most important feature was the inclusion of the NHS as an equal partner. It was made clear, since the very first call, that BRC status applicants should present a University / NHS partnership, and they should be able to demonstrate a sound working relationship between the two partners. The novelty brought about by the partnership requirement was that the NHS and its institutions were given a voice in research agenda setting and governing. In other words, the NHS was vested with similar authority as Universities over research activities. As a result, academic researchers were now subjected not only to norms and procedures from their own respective academic units, but also to those of partner hospitals.

> "We are very keen on encouraging them [academic researchers] to come off their campus in to ours, and I mean that metaphorically more than anything else, but they need to embed themselves in the NHS culture, in the NHS ethos and what we're about. I think it is about having a buy in at a patient level, at a clinical level, which is what we're trying to encourage here. It is not just research for research sake and directions of research, you know, there's a lot of our academics of clinical time, a lot, you know, we encourage that, we try and get it embedded in this process, in this campus and in this ethos". (Cambridge BRC member)

In this vein, funding was one of the primary resources given to NHS hospitals. Effectively, the responsibility over all research procurement and related administrative tasks was entrusted to hosting hospitals. However, the initial allocation of this new stream of funding into NHS accounts was problematic for all BRCs. By 2007, the influx of the so-called Cullyer funding from the DH for research and development activities in hospitals was stopped. Concurrently, the new BRC funding started to flow in. The evidence from all BRCs consistently describes the initial struggles to ring-fence BRC funding and allow its use for BRC projects only.

> "So from the NHS Trust point of view they could easily say, and indeed did to a certain extent, oh that's great. We used to get in our case about 13 million pounds of Cullyer money and now we're

> getting 13 million pounds of the biomedical research center money, so that we've maintained the status quo. Whereas we had to move on from that and had to actually free that money up and allow it to be used in the way that we'd said we were going to use it in the BRC application. So that was the major battle at the beginning." (Cambridge BRC member)

Moreover, the actual location of BRC offices within NHS hospital premises was a further, albeit more symbolic, resource provided. While the original bid document was not clear about the actual location or setup of the BRC structure, it was assumed that BRCs should be embedded into or close to hospital R&D departments. Imperial, UCL and Oxford BRCs created a separated governance group close to the hospitals' R&D departments –separate but sharing some common resources. Kings made the overall BRC program an element of the broader R&D department at the hospital. Finally, Cambridge created a so-called "virtual organization" within the hospital's R&D department, run by the very same people. In practice, this organizational and physical location also created a new space for both scientific and clinical communities to meet.

> …but it's an NHS phenomenon. It's, we have a, we have a collocated, the BRC is part of the R and D infrastructure that sits within one location with actually all our NIHR networks, so the comprehensive network, the primary care network and the governance team all sit together and all mix and match. So there's open space with everybody working with everybody else, but it's an NHS function. We have links through our, on our R and D Board and our R and D Exec, with the head of the college, if you like, the medical school and finance, HR, corporate functions, but essentially it's all run through and certainly the finance is all dealt with by the NHS. (Kings BRC member)

A second associated element was joint governance. The five comprehensive BRCs established a joint governing structure, for they were perceived as requiring joint bodies at a number of levels to ensure genuine Trust-University coordination for Research and Development strategic and operational plans. At the most salient level, every BRC established Partnership Boards, whose role was to ensure strategic cooperation at a high level, facilitating the activities of the Centre, liaising with planners and policy makers (including the NIHR Board), and promoting strategic alliances with external bodies in the NHS, academia and industry. The Board had ultimate responsibility for BRC success and financial accountability. The Boards at the four cases studied consisted of the following members: from the Trust, the Chief Executive, the Medical Director, and the Director of Finance; from the University, the Vice Chancellor / President, the Head of the Medical Sciences Division, and, at Oxford and Cambridge, the Regius Professors of Medicine, among others.

> "I mean I think one of the big challenges for us was, you know, quite how the university fitted in with this and the approach that we've used is really a lot of our stuff is sent to the university, but by bringing the NHS in to that. Actually I think the whole process has brought, has made the university and the NHS actually adopt processes which have joined them together, so they're not

> operating separately like they were before. But we've joined up the research offices between the university and the NHS, for example for, whereas before we had separate ones and I think that was facilitated by the – so I think the message is we have more joined-up structures between the university and the NHS." (Cambridge, BRC member)

Furthermore, this joint governance scheme was catalytic in the creation of joint university-trust R&D offices (for example, at Oxford).

A third identified element that helped rearrange commitments and influence the setting of academic research agendas towards translational research efforts was the introduction of multiple metrics. Together with the more traditional outcome measures in academia (such as number and type of publications, impact factors, etc.), a broad set of metrics was requested by the NIHR (including both outcome and process ones), organized around the following categories: publications, patient involvement (number of patients recruited for studies and clinical trials), intellectual assets (number of new patents, licensing deals agreed, spin-off companies established, intellectual property revenues, etc.), training (number of research students in BRCs, awards received, number of taught courses), and expenditures (under-spending). The overall purpose was to broaden the evaluation process in order to include elements that encouraged researchers to pursue translational research. In line with goal-setting theory (Latham, 2006), the plurality of metrics has tried to ensure that not only academic goals but also clinical and health related ends are pursued in every research project.

> So I think that was the thing the BRC drove a change in, you know, what is the impact of this research on patients in this case but, you know, not only what journals had it been published in but actually has it made any difference, and if not, will it make a difference to grant incomes, you know, a high degree of supervision, they would need individual assessment. And then in terms of the theme, I think they looked at the contributions of the individuals but I think more importantly for the themes, that was when they looked at the impact. They looked more at what is it that this theme has delivered that might have changed, for example, the way healthcare is delivered or could be delivered in the UK. Has there been any benefits for patients that will come of this five years' investment? (UCL BRC member).

Finally, interviewees' narratives have revealed a last element regarding the release of normative commitments: the flexible nature of BRC funding. As compared to other funding sources, BRC funding provides more freedom to invest in infrastructure and capacity building. Unlike other sources, it is regarded as not excessively focused on specific research projects. Cambridge's BRC strategy proves paradigmatic in this respect, although this is a common feature across all BRCs. From the onset, Cambridge's BRC strategy has been one of primarily investing in infrastructure projects, largely through core facilities (such as Addenbrooke´s Clinical Research Centre, the Core Biomedical Assay Laboratory, the Eastern Sequence and Informatics Hub, the Micro-Array

core, the MRI Core, the Tissue Bank, etc.). Such flexible funding helps span normal disciplinary boundaries, fostering collaboration across research themes.

> Our model here, we heavily invest in infrastructure. We spend a lot of our money, you know, we don't have a lot of projects, we invest in the facilitating side of things and we'd certainly make it much simpler. I mean the fact is local politics, local money dictates the agenda often and it would not help the BRC if people would revert to their silos, they would revert to their themes or therapeutic areas. Actually we use the BRC here, as I say, to encourage people across, to cross over, to start working with counterparts from away from academic campuses on here, and a lot of the investment has gone in to infrastructure and equipment". (Cambridge BRC member)

> …we've built the infrastructure to do. So it was important we got that right because for the last, for the first cycle of the BRC we actually built a lot of infrastructure that we didn't have. So we built this floor, the fifteenth floor which is the Clinical Research Facility, this whole tower here has got a translational research infrastructure that didn't exist before the BRC happened. So all of that infrastructure has been, it's this experimental medicine piece, not to drive phase two trials. So that's what I think translational research is in the context of the BRCs, but that clearly fits in to a wider spectrum, but I think that's what our unique offering is, that we could do that because we have basic science, we have patient groups, we have infrastructure, so actually we can make those observations, those first in man observations and have a, as you said, like these flexible proof of the concepts, what's the concept we're trying to prove. We'll prove it and then either that provides interesting data to feed back in to a new concept or it proves the concept so well that it then gets scaled up within an AHSC and we don't, we don't throw it over the wall but then it's scaled up because of the BRC's part and the Academic Health Sciences Centre. (Kings BRC member)

Honoring "normal" commitments. As noted above, the main goal of the NIHR's BRC program was to leverage the findings from fundamental biomedical research to drive innovation in the prevention, diagnosis and treatment of ill-health. Therefore, what was intended was a change from within. Any radical departure from the constellation of shared commitments or 'disciplinary matrix' (Kuhn, 1970) would have hampered this purpose, as such a critical departure would have created an inner conflict among scientists who are active members of their communities and, hence, bearers of well-established and accepted norms and commitments. The BRCs studied -and the NIHR itself- have shown a great deal of respect for academic practices and customs. Honoring "normal" commitments in science seems to have allowed scientists to undertake research that was somehow different (applied, multidisciplinary, focus on clinical outcomes, etc.) without compromising their identities and/or membership to their original scientific community.

The evidence on the original selection of themes at all BRCs seems to initially prove this point. Although it was made clear in the bid, resonating with current policies (e.g. DH 1999), that proposed research themes should somehow reflect the list of UK health priorities, leeway was given to NHS/University partnerships to actually choose what and how many research themes

they would have. Even internal theme compositions and organizing methods were left for BRCs to decide. Interviewees' narratives clearly reveal that a shared understanding -about whom, or which groups, were better prepared for this program- permeated decisions.

> We knew exactly what our strengths were clinically and I've talked about those already, and they actually were our strengths also academically in the main, so were big building blocks to the medical school and the biomedical science school which are the two underpinning academic blocks in this area of translation. So I guess we did ask in other – once there was a thought of money for their research, other people did come to the table and, and we did try to morph them into either the themes we thought were right or see whether they were viable themselves and, and there were none that were viable. (Kings BRC member)

UCL's case was different and yet respectful of UCL tradition. There was an open call across the two partner institutions for researchers to submit theme proposals, whose academic merits were evaluated, and sixteen themes were finally chosen in an internal competition. "It was [done] in typical UCL fashion; that was a typical bottom-up approach" (UCL BRC member). We found further evidence of this conservatism concerning some academic norms in research progress monitoring practices. Over the studied period (2008-2012), the control of the evolution of every theme and its corresponding research projects was described by interviewees as "light- touch", "not heavy-handed", and "trust-based". In contrast to other funding institutions, where frequent and detailed reports on both research progress and money utilization have to be submitted, BRCs' approach allowed for a great deal of freedom and flexibility for researchers not only in the use of funding but also in outcome reporting. There were some informal reporting instances carried out by theme leaders (e.g., at theme leaders' monthly meetings) and only one formal reporting instance: the annual report (requiring every research theme to submit a brief description of its research projects' evolution and some metrics, like publications, number of patients enrolled in clinical trials, patents granted, etc.)

> "The small charities but are, to me, like having an interfering mother asking you how you're doing all the time and you just can't get on with the work because they're still asking you for a report after the first six months and then a report after the next six months. And you really feel strangled, strangled in a way because you just want to get on with the research and of course there are setbacks and things that don't always go to plan, but yet you've got to write these all out and it takes time out of what you should be doing. That is extremely annoying and it does put me off applying for the smaller charities. I think that the BRC are in between. There is a great deal of trust and respect on one if you do get awarded a grant, yet you do have to come up with the yearly report, which isn't too long, it's not too detailed and you have enough notice". (UCL BRC member)

> "It's probably not overly heavy-handed and it's probably reasonable, you know, clearly, you know, we are answerable to government in the end who are supporting this activity, there needs to be information fed back through the system to say we are making progress." (Kings BRC member)

A final piece of evidence for such a respect for scientists' autonomy to govern their own activities was the freedom BRCs were given not only to select research themes but also to stop them. Without any NIHR interference, all the BRCs studied chose to stop a small number of themes during the 2007-2012 period. While this is not surprising in itself, the commonalities across all four BRCs on how and when they made these decisions proved most striking. First, all BRCs decided to stop/rearrange a few themes just after the formal midterm evaluation (2010). And second, all BRCs somehow externalized the decision, seeking legitimacy, to Scientific Advisory Boards, which made the final recommendation on this respect. Such care in evaluating and deciding to cut the funding of research colleagues resonates with the description made by Dawson and colleagues (1995), suggesting that in long-term tenure communities, members are much more aware of –and, hence, much more cautious of- potential conflicting actions that can undermine and have lasting effect on their social relationships and social capital (cf. Nahapiet & Ghoshal, 1998). In other words, if not carefully managed, these decisions may have entailed a potential hazard to their community memberships.

Perceived Outputs. Common across the interviewees' narrative is the perception that the BRC program had a very slow start, largely as a result of the delay in recruiting new staff funded by BRC awards and in establishing core facilities. While the amount of funding allocated to the Centers was limited to 50% of the amount for future years, in anticipation of start-up delays, it proved challenging for a number of BRCs to spend even this reduced allocation. By the start of the third year (2009-2010), both management and scientific members had gained a clearer understanding of the BRC program's role and impact.

> (…) and what started was a process that was more directed at starting to actively fashion the shape of the BRC. While it was just being a bunch of people who happen to work in the hospital who'd been inherited and put in to themes, it was about pruning, shaping, pushing some people back in to the NHS, hiring some more people. That started to gather momentum in maybe the last two years of BRC1 and that's a more, so it's a transition I think from pre-BRC1, I'd say quite a passive approach to strategic management of the translational portfolio, to the end of BRC1, something where we actually could articulate a near-term strategy for how to manage people and how to manage the organization in such a way that it was aligned to the strategic goals of all the other organizations we interact with. (UCL BRC member)

Overall metrics seem to confirm this gathering momentum. The level of research activity and associated outputs funded by the NIHR's BRC awards was relatively limited; however, this was to be expected, given that the emphasis in the early years of the BRCs' existence was inevitably

focused on setting up systems and structures as well as initiating new research projects. For example, year-on-year publication output increased by 0.14% between 2010/11 and 2011/12, with the average number of publications per BRC rising from 92 in 2008/09 to 176 in 2009/10, to 283 in 2010/11, and to 283.4 in 2011/12 (it should be noted that the reported averages are higher for the comprehensive BRCs studied). Overall publication output by BRCs has grown almost 14 times since 2007/08. A significant year-on-year increase was also registered in patient recruitment for all BRC studies. In 2007/2008, there were 68861 patients; in 2008/2009, 90037 patients; in 2009/2010, 106870 patients; in 2010/2011, 411773 patients (this figure does not include a reported 3,5M patient accrual to one study in one of the BRCs, to allow for a better comparison of all patient recruitment data), and 1080644 in 2011/2012. Similarly, there was an overall increase in BRC research activity from 2007/08 to 2011/12.

Based on scientist' narratives, the interpretations of perceived BRC program outputs and impact can be clustered in two groups. First, the flexible nature of funding and its focus on infrastructure and capacity building have been widely viewed as having both a leverage and catalytic effect. Many theme leaders have described how the nature of this funding has helped to propel research projects, leveraging research findings and driving translational outcomes at a faster pace.

> "What we do is clinical trials and some applied laboratory research to evaluate those vaccines. So overall the theme hasn't change we still the vaccines team but we couldn't have done is the amount of work we have done over that time so is quantity and I think the other thing is that there are some projects which would have been difficult to fund anywhere that we've delivered, very important projects. Because of the time of getting the funding, but also because the type of questions that we are addressing are of national and international importance but industry does not want to fund them because they are not directly of interest to them." (Oxford BRC member)

> "Well there are often projects that appeal at a local level (…) there are projects that are steppingstones that a local level that can, you know, capacity-build or improve the infrastructure. They are the sort of pieces of equipment, for example, that would be very difficult to fund from outside but enhance our research practice immensely. An example of this is the Lambeth medical MR compatible ventilator, incubator and, you know, this is an expensive piece of equipment, we're talking about a third of a million, impossible to get from outside. But because UCL has had such a fantastic track record and imaging and imaging tiny and sick babies in the magnet, this is something that appealed I think to them and they felt that this track record needs to move on to the next stage to keep ahead of the world. And so it's, it's quite, they're very much projects that can play to the strengths of oneself or one's institution I think." (UCL BRC member)

Second, such a focus on creating common facilities and areas for researchers and clinicians from different disciplines to share and collaborate has had a perceived effect on lowering a number of barriers. First and foremost, theme leaders described how, over a five-year period after BRC program inception, the barriers between NHS and academic institutions have become lower or, at

least, laxer. Second, researchers also mentioned that the traditional silo structure surrounding disciplines and diseases has grown softer, to the extent that collaboration across disciplinary fields and between researchers and clinicians has influenced research undertakings.

> "I think separately the BRC has been a very galvanizing influence in bringing the Trust and the university together. And so this is the issue of different cultures meeting and the finance that the BRC has provided has given both institutions, the university and the NHS, a common purpose, how do we spend this money for the benefit of humans and for the success of both the institutions" (Oxford BRC member)

> "But I think the biggest change that I've noticed over the last, since these came into existence, was disciplines used to be very sort of silo-based, you know, we did neurology, cancer did cancer, psychiatry did psychiatry and we all did our own thing. And as technologies have evolved, it's clear that the need to sit in your own silo and do your own thing is useful to a point but isn't clearly all that there is to the research because of these sort of theme-cutting, crosscutting themes really. So, and I think this has been a major change. So, you know, when we want to study immuno phenotypes in neurodegenerative disorders, we want to do genetic studies in dementias, it's exactly the same processes they'll be using for looking at it in rheumatoid arthritis, inflammatory bowel disease or whatever. So there's been much more, there's been a greater attempt to sort of integrate across the campus crosscutting disciplines and themes so that we all basically subscribe to how we're going to do genetic studies, how we're going to sort bio samples and how we're going to do imaging in the future. And so I think that has been a major change on the research landscape and that I think has been quite hard because a lot of people of the older school are very much used to running their own department, they're not used to being part of an integrated biomedical research campus. And that seems to me to have been the biggest change, you know, that there's definitely been more effort to try and integrate things around common technologies. (Cambridge BRC member).

Study 2: Quantitative Data and Analysis

To better understand the effect of hybrid governing on scientists' research, we collected and analyzed data on the publication record of the 51 BRC research leaders from the four BRC centers. The reason is straightforward. If the new hybrid approach matters for the type of work performed, these effects should be visible in the scientific output of the BRC leaders. So such an analysis can provide additional evidence to evaluate our framework.

Of course, establishing the causal effect of BRC membership on scientific output is far from straightforward. The main limitation here is the lack of random assignment. A simple analysis comparing the BRC leaders' output before and after BRC membership would be problematic as their individual characteristics are likely to be endogenous to the choice of becoming BRC leaders. BRC scientists are chosen and there are good reasons to believe that their individual characteristics play an important role in this process. To overcome this challenge, we employ a combination of matching and difference-in-difference analyses that allows us to create a comparison group that

can be used to evaluate the output of our scientists. These control scientists essentially allow us to observe, albeit imperfectly, what would have happened to the BRC leaders had they not joined the BRCs and, thus, assess the effect of BRC membership on their knowledge output.

Quantitative Data

We collected data for all full professors in departments of medicine from the top 30 research universities in the UK. To identify these institutions, we relied on RAND Europe's bibliometric analysis of health research in the UK during the 2002-2006 time period. This choice was driven by the selection criteria for BRC membership. As explained before, BRC status was awarded based on the perceived quality of research output of universities and emphasis was put on more objective publication-based measures. Hence, full professors at the top research-intensive universities in the UK coincide with the population of potential BRC leaders.

We identified 1,779 scientists, including the BRC leaders, and then collected data on their publication history from 1992 to 2013 using PubMed. This is a search engine maintained by the US National Institutes of Health (NIH) and includes the Medline database which provides bibliographic information for all articles published in medical sciences and related fields. Importantly, Medline reports detailed information on the subject matter of all the papers listed using the medical subject headings, or MeSH terms. This is a standardized indexing system for Medline publications and is maintained by the US National Library of Medicine. The advantage of relying on this classification is that MeSH keywords are assigned by trained and professional librarians, not by the authors themselves (Coletti and Bleich 2001). This ensures consistency and objectivity in describing the paper subject matter and allows us to make meaningful comparisons between published papers.

Nevertheless, a key challenge in this setting is author name disambiguation, or how to accurately identify the publication track record of the scientists in our sample. This is not a trivial task given that many scientists do not include full publication lists on their websites and common surnames can be associated with thousands of published papers. We therefore relied on the 'Author-ity' tools developed by computer and bioinformatics scientists to tackle this problem specifically for the case of Medline (Smalheiser and Torvik 2009; Torvik and Smalheiser 2009). 'Author-ity' relies on models that use various information sources, such as coauthors, affiliations, keywords etc., to provide probabilistic estimates of authorship. This method has been found to perform very well, resulting in very low percentages of Type I or II errors (Torvik and Smalheiser 2009).

Key variables

We focused on three key outcome variables, all relying on MeSH terms, to gauge the effect of BRC membership on publication output. The first, *self-proximity*, is a measure of relative change in the direction of a scientist's output and is calculated as follows:

$$self - proximity_{it} = \frac{1}{N}\sum_{it} \frac{P_{nit}P'_{i(t-1,t-2)}}{\sqrt{(P_{nit}P'_{nit})\left(P_{i(t-1,t-2)}P'_{i(t-1,t-2)}\right)}}$$

where P_{nit} is a multidimensional vector representing the distribution across MeSH terms of paper n=1,..,N authored by i and published in year t while $P_{(t-1,t-2)}$ is a multidimensional vector representing the distribution across MeSH terms of all papers authored by i and published in year t-1 and t-2. This measure essentially captures how similar (in terms of MeSH terms) are a scientist's publications in year t compared to her own publications in years *t-1* and *t-2*. This is calculated using a measure of uncentered correlation (Jaffe 1986) and is bound between 0 and 1, with high numbers indicating that the articles published in year t by author i are characterized by similar mesh terms as compared to the articles published by the same author in the previous two years.

Then, we calculated two more variables based on a measure of paper novelty. Novelty here is calculated by examining the dyadic combinations of MeSH terms for each article and then checking if these have appeared in the literature over the past 10 years (Boudreau et al. 2012). For example, assume a paper has n MeSH terms. We can identify $n(n-1)/2$ dyadic combinations of MeSH terms and check if these have appeared in any published papers. If say half of these combinations have appeared while the rest are novel, then the paper has a novelty score of 0.5. As Boudreau et al. (2012) note, the use of 10 years as opposed to the entire literature as a benchmark has a minimal effect on the calculated measures. Based on this, we subsequently calculate *paper novelty* as the percentage of papers published where the novelty score is higher than 0, i.e. the paper has at least one novel combination of MeSH terms, and *extreme paper novelty* as the percentage of papers where the novelty score is 1, i.e. all MeSH term combinations all novel. Thus, while *self-proximity* is based on a 'within-author' comparison, these measures capture the extent to which papers depart from the existing literature.

Econometric approach

As noted before, the main challenge for our study is to identify a suitable group of control scientists with which to compare the publication output of our treatment group, i.e. BRC leaders. In doing so we follow standard practice that uses observable characteristics to create a

counterfactual group and then compare the relative change in the variables of interest across groups and time (Azoulay et al. 2010; Fang et al. 2014). The difference-in-difference estimator compares the change in key variables across the pre- and post-BRC time period and across the treatment and control groups. In particular, the pre-BRC period is defined as between 2002 and 2007 inclusive while the post-BRC period is between 2008 and 2013 inclusive. It is true that the BRC centers were created at the end of 2006 but we consider 2008 as the first BRC year to account for the publication lag. Unlike in social sciences, the publication cycle in medical sciences is much faster so a one-year lag seems appropriate.

Yet, for this type of analysis to provide meaningful results it is important to identify control scientists whose output follows similar trends to that of the BRC leaders, that is the so-called 'parallel trends assumption' should not be violated (Lemmon and Roberts 2010; Roberts and Whited 2012). In our context, this suggests that BRC leaders and control scientists should behave similarly in terms of growth rates for *self-proximity*, *paper novelty* and *extreme paper novelty*. In fact, this is the key identification assumption and similarity in terms of the level of *self-proximity* or *novelty* is not a necessary condition.

In more detail, we used a two stage process to create the control group. First, for each individual BRC leader we create a sub-group of 'eligible' control scientists from the population of scientists we collected. The reason for this is that we want to match each BRC leader with a scientist whose research falls in the same practice area (e.g. cancer, ophthalmology etc.). Failure to do so could bias our results if the different practice areas face different opportunities for science to progress over different time periods. We do not have a clear classification scheme to assign our scientists to practice areas though as self-reported assignments are not standardized and often not updated. So, we devised an alternative approach. We calculated a measure of practice area proximity between each BRC leader and the remaining 1,728 scientists using MeSH terms. This measure is very similar to *self-proximity*, but employs an 'across-scientist' comparison as follows:

$$practice\ area\ proximity_{ij} = \frac{P_i P_j'}{\sqrt{\left(P_i P_j'\right)\left(P_i P_j'\right)}}$$

where P_i and P_i are multidimensional vectors representing the distribution across MeSH terms of all papers published by BRC leader *i* and scientist *j* during the pre-BRC period. Subsequently, we keep the top 10% of most proximate scientists and create a list of 'eligible' control scientists for each BRC leader. While far from perfect, this approach ensures similarity in terms of research output that relies on the far more objective MeSH term classification scheme.

In the second stage, we use a matching procedure where we identify the 'nearest neighbor' for each BRC leader from their individual 'eligible' control groups. In particular, we calculate the Mahalanobis distance (Rosenbaum and Rubin 1983, 1985) between BRC leaders and eligible scientists based on the following variables: sex, number of years passed between first paper published by the scientist and BRC creation, average number of MeSH terms per paper during the pre-BRC period, average number of coauthors per paper during the pre-BRC period, average number of papers published per year during the pre-BRC period and the growth rate of average number of papers published per year during the pre-BRC period.

We also include the growth rates of key outcome variables to ensure that the parallel trends assumption is satisfied. We include: the growth rate of *self-proximity* during the pre-BRC period, the growth rate of *paper novelty* during the pre-BRC period and the growth rate of *extreme paper novelty* during the pre-BRC period. In addition, we include for all three key variables the growth rate for the year before the BRC creation, i.e. 2007. This is to ensure that the chosen control scientists are at a similar publication cycle with the treated scientists. Often, *novelty* or *self-proximity* are characterized by a life cycle where scientists initiate new projects, resulting in more 'novel' and 'distant' publications, and subsequently followed by less novel and distant publications in the next year or two as scientists build on and extend their existing work. Including these variables ensures that we capture this dynamic and create a control group of scientists in very similar publication cycles.

Our final dataset then is a group of 102 scientists whose publication output we observe over a 12-year period. Based on the quality of the matching process we can infer the causal effect of BRC membership by comparing the difference of growth trajectories in the key variables of interest during pre- and post-BRC periods and across the two groups.

Results from Study 2: Quantitative Analysis. In this part, we present the results of the analysis of the publication output of BRC leaders. We start by presenting the univariate comparisons between BRC leader and control scientist characteristics as well as their corresponding *t*-statistics in Table 4. We can see that BRC leaders have more males, started publishing earlier, include more MeSH terms in their papers, have more coauthors and publish more papers per year as compared to all scientists we have included as potential control scientists. After the matching process though, only the difference in the number of papers published remains significant. This helps remove any residual heterogeneity between the two groups. In addition, we find no statistical difference in the pre-BRC growth variables between BRC leaders and control scientists, a fact that supports the validity of the parallel trends assumption. The two groups behave similarly in terms of the key

publication output measures studied during the pre-BRC years so any changes we observe during the post-BRC period can be more convincingly attributed to BRC membership.

Insert Table 4 and Graph 1 about here

Table 5 presents the results of the difference-in-difference estimation and two clear findings emerge. First, we find that BRC leaders reduced their *self-proximity* over the post-BRC period as compared to control scientists and this difference is statistically significant at the 1% level. This suggests that BRC membership induces scientists to explore more and undertake research in different research areas as compared to their past activities. This result is very important as it confirms the findings from our qualitative study and the idea that BRC membership changes the direction of scientists' research efforts. Graph 1 helps us understand the dynamics of the process. It presents the standardized difference in self-proximity between the two groups for each year during the study period along with corresponding standard errors. During the pre-BRC period, the BRC leaders had higher values of *self-proximity*, suggesting that they were more inward looking in terms of their chosen research projects. This difference is relatively stable, with the exception of one year, and BRC leaders have roughly 20% higher values of *self-proximity* as compared to control scientists. Things change fast after the BRC creation though as BRC leaders start work on different projects relative to their past record and their publication are characterized by lower self-proximity, roughly 15% lower than that of control scientists.

A similar picture emerges when looking into the novelty measures. Both *paper novelty* and *extreme paper novelty* increase for BRC leaders as compared to control scientists, with these differences being statistically significant at the 5% level. This suggests that BRC membership increases the novelty of the scientific output, a finding that reinforces the notion that being member of multidisciplinary teams with different logics can help overcome existing constraints. Graphs 2 and 3 present this process over time again using the standardized differences in *paper novelty* and *extreme paper novelty*. Looking at both measures, BRC leaders' output is less novel during the pre-BRC period as compared to control scientists. Yet, we can observe a a large increase in *paper novelty* following the creation of the BRCs, with BRC leaders producing on average almost 10% more novel papers, i.e. paper with at least one novel combination, during the post-BRC period. The increase is even more dramatic for *extreme paper novelty*, with BRC leaders producing almost 60% more papers where all MeSH combinations are novel to the

literature. These results do not only point to the effect of BRC membership on publication output but also highlight the magnitude of such effects.

Insert Table 5 and Graph 2 and 3about here

Discussion and Conclusion

In this study, we integrate Institutional logic literature with research on Sociology of Science to introduce and explain the features and effects of hybrid governing — control and coordination mechanisms that combine governing practices of multiple logics that help anticipate resistance in stable complex fields — on the undertaking of translational research. This conceptualization of hybrid governing extends research on hybrid organizing by showing how disparate – i.e. from different logics – governance practices can release some normative commitments, providing opportunities for both leveraging the science base and, at the same time, opening it up to new questions and methods. We suggest that the realization of these outcomes is contingent upon a balance between governance practices that intend on one hand to honor well established principles and practices of the constituent logic (i.e. academic science), and on the other hand to introduce change via the rearrangement of different governance practices and vested actors.

To study hybrid governing, we conducted a mix method longitudinal study of the largest translational research program in England since its inception in 2007 to 2013. Such level of access over an extended period of time gave us an unusual opportunity to understand translational research and the conditions that might affect it, while the analyses of these data yielded several insights. First, we found that the NIHR's translational program, through the creation and funding of BRCs in England, has attempted to influence research agenda setting in biomedical sciences. Our research elucidates a number of hybrid strategies that enabled this goal, such as vesting the NHS with authority, institutionalizing joint governance structures, introducing multiple new metrics and goals, and building a flexible funding scheme. With the ultimate goal of releasing some of the normative commitments in science and opening up spaces for new questions, problems, and methods to be pursued, the UK's DH has tried to accelerate the adoption of a translational agenda. Second, despite the fact that this initiative aimed to produce changes in scientists' agenda and practices, our findings show that this was not done in a radical way. In line with the more conservative aspects of a normal science, BRCs implemented a series of practices that honor already legitimized and established scientific procedures and customs. Such hybrid

governing is coherent, as the DH's overall intention was to leverage the existing science base in order to drive clinical developments to tackle the UK's health priority.

Overall this study also extends the research literature on Sociology of Science. Our findings suggest that the hybrid governing approach mitigated potential conflict for participating scientists, avoiding a radical departure from the constellation of shared commitments of the scientific communities (Kuhn, 1970). Such a conflict could have limited their capacity to leverage translational research on the extant science bases. At this point, Fleck´s 1936 work on epistemology and collective bonds becomes directly relevant. Fleck argues that member of a thought collective develop a certain bond, a feeling of group solidarity. The force that maintains the collective and unites its members derives from the community of the *collective mood*. This mood produces the readiness for an identically directed perception, evaluation and use of what is perceived –i.e., a common thought-style (1936, V). In a similar vein, Kuhn (1962) upholds that such a consensus allows for an agreement on fundamentals (i.e. type of problems, procedures and instrumentation, scientific language, metaphysics, and so forth) in normal sciences. Significantly, the hybridity found in the BRC initiative (its intention to both *rearrange* and *honor* established normative commitments) seems to have softened potential antinomies in normal science practice (as the undertaking of translational research introduces practical, applied, and multidisciplinary foci into hitherto theoretical, pure, and disciplinary ones). Our study results also suggest that honoring of scientific practices and customs has also softened the potential inner-conflict that might have been brought about by the juxtaposition between academic science and care logics. Considerable anecdotal and empirical evidence indicates that this approach has positively impacted both the pace of translational research agenda adoption of and its outcomes.

Another contribution of this paper is the analysis of how extra-scientific factors play out, influencing and conditioning scientific practices and outcomes. As in earlier studies, our findings suggest that public and political appeals for science regulation often stem from dissatisfaction with its practical accomplishments, as scientists fail to provide specific solutions to public needs or concerns. Gieryn (1983) illustrates this point with the analysis of the impact of the 1982 report entitled *Scientific Communication and National Security*, produced by the National Academy of Sciences' Committee on Science, Engineering and Public Policy (NAS, 1982). With this report, the U.S. government intended to expand government control over the circulation of scientific knowledge to avoid information leaks that could potentially compromise national security. Such a straightforward attack on some of the imperatives that comprise the ethos of modern science,

like communalism and universalism (cf. Merton, 1973), was strongly and unanimously rejected by scientific representatives, who argued that science "should remain free from government restraints, and that national security will be more effectively attained not through controls on science but through preserved autonomy and enlarged resources to enable American science and technology to retain its international pre-eminence" (Gieryn, 1983: 790). In contrast, the overall BRC initiative has been intended to drive a change from within, without fundamentally altering or threatening such a constellation of shared scientific commitments. The evidence suggests that this has had a positive impact on the adoption of the translational agenda, avoiding the risk of scientists' reverting to their disciplines, themes or therapeutics areas.

Finally, some of the limitations of our study unveil a number of areas for future research. First and associated with the theoretical arguments elaborated above, the vesting of authority onto the NHS has been –by design– limited to the BRC/ translational research domain. Moreover, scientists' BRC engagement and membership have been voluntary. These two characteristics have reinforced the influence and success of this initiative. Future research might seek to explore similar initiatives with compulsory scientist involvement or the nature of interventions more prescriptive. Second, our empirical results are based on data from the English NHS system. While BRCs in particular have been recognized as internationally leading translational medicine centers and, more generally, British health-related sciences have long been acknowledged for the quality and impact of their scientific breakthroughs, some comparative work on similar initiatives in other countries (such as Canada, the United States, and Sweden) may provide a fuller picture of the more contingent factors affecting the implementation of translational research. Third, while we have gathered information on both perceived outputs and actual NIHR metrics used to evaluate the success of this initiative, by design we have not collected data on the actual benefits of translational research. Measuring the potential benefits afforded to patients, the NHS and society at large by BRCs' research efforts, or providing a performance metric to measure the potential contribution a new project can make to BRC aims could contribute to answering critical questions on the value of translational research undertakings.

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Table 1 Case Overview

NHS Organization	Cambridge University Hospital NHS Foundation Trust	Guy's and St Thomas' NHS Foundation Trust	Hammersmith Hospitals NHS Trust & St Mary´s Hospital NHS Trust	Oxford Radcliffe Hospital NHS Trust	University College London Hospital NHS Foundation Trust
Academic Partner	University of Cambridge	King´s College London	Imperial College London	University of Oxford	University College London
# of themes at the inception (2007)	11	7	16	14	16
Full list of research themes	+Cancer +Cardiovascular Medicine +Obesity, Diabetes & Metabolic Disorders +Imaging +Infection and Immunity +Medical Genetics +Musculoskeletal Disorders +Neurosciences +Improving Outcomes in Transplantation +Women's Health +Translating Biological Science Into Clinical Care +Capacity Development and Training	+Asthma & Allergy +Managing Atherosclerosis Risk and Ischaemic Injury +Emerging diagnostic and therapeutic approaches in organ and cell transplantation +Infection and Immunity: harnessing natural defences to prevent diagnose and treat autoimmune infectious and inflammatory diseases +Molecular profiling, targeting therapies and outcomes in cancer +Severe skin disease: diagnosis, prevention and treatment +Oral Health: Novel prevention, Innovative Diagnosis and Minimal Intervention	+Cancer +Cardiovascular Disease +Child and Adolescent Medicine +Genetics and Genomics +Haematology +Hepatology and Gastroenterology +Imaging +Infection +Endocrine, Metabolism and Diabetes +Neurosciences +Public and International Health +Renal Medicine and Transplantation +Reproductive Medicine and Development +Respiratory Medicine +Rheumatology +Surgery and Surgical Technology	+Bioengineering Innovation & Technology (BIT) +Blood +Brain +Cancer +Diabetes +Genetics +Heart +Imaging +Immunity +Infection +Stroke +TRIO Cohorts +Vaccines +Women	+Education & Training +Cardiovascular Disease +Anaesthesia & Critical Care +Cancer +Cellular & Gene Therapy +Infectious Disease +Long Term Conditions +Women & Neonates +Gastroenterology & Hepatology +Imaging +Neuro-imaging +Neuro-diagnostics +Neuro-degeneration +Neuro-therapeutics +Pain & Headache +Oral Health
Collaboration NHS / Univ.*	42%	29%	43% and 29%	48%	61%
Collaboration NHS / Univ.**	Not available	42%	57%[+]	57%	55%

*Collaboration between NHS organizations and universities on the top 20% most highly cited publications (HCPs), 2002–2006

**Collaboration between NHS organizations and universities on the top 20% most highly cited publications (HCPs), by April 2013
+This figure is only indicative as include Hammersmith Hospitals NHS Trust & St Mary´s Hospital NHS Trust, Charing Cross Hospital, Queen Charlotte's & Chelsea Hospital and Western Eye Hospital, as these hospitals merged in 2007 into a single NHS Trust

Source for 3 and 4 row: RAND 2006; 2013

Table 2 Description of Case informant data

BRC	Oxford	Cambridge	UCL	Kings	Imperial	Others
Number of Interviews	14	10	8	10	4	10
Type of informants	Scientists R&D Director BRC Manager BRC Deputy Manager	Scientists BRC Director BRC Manager	Scientists BRC Director BRC Manager	Scientists BRC Director BRC Manager Finance Res.	Scientists BRC Director	NIHR responsible, NHS consultants, etc.

Table 3: Overview of the progression of categorical analysis

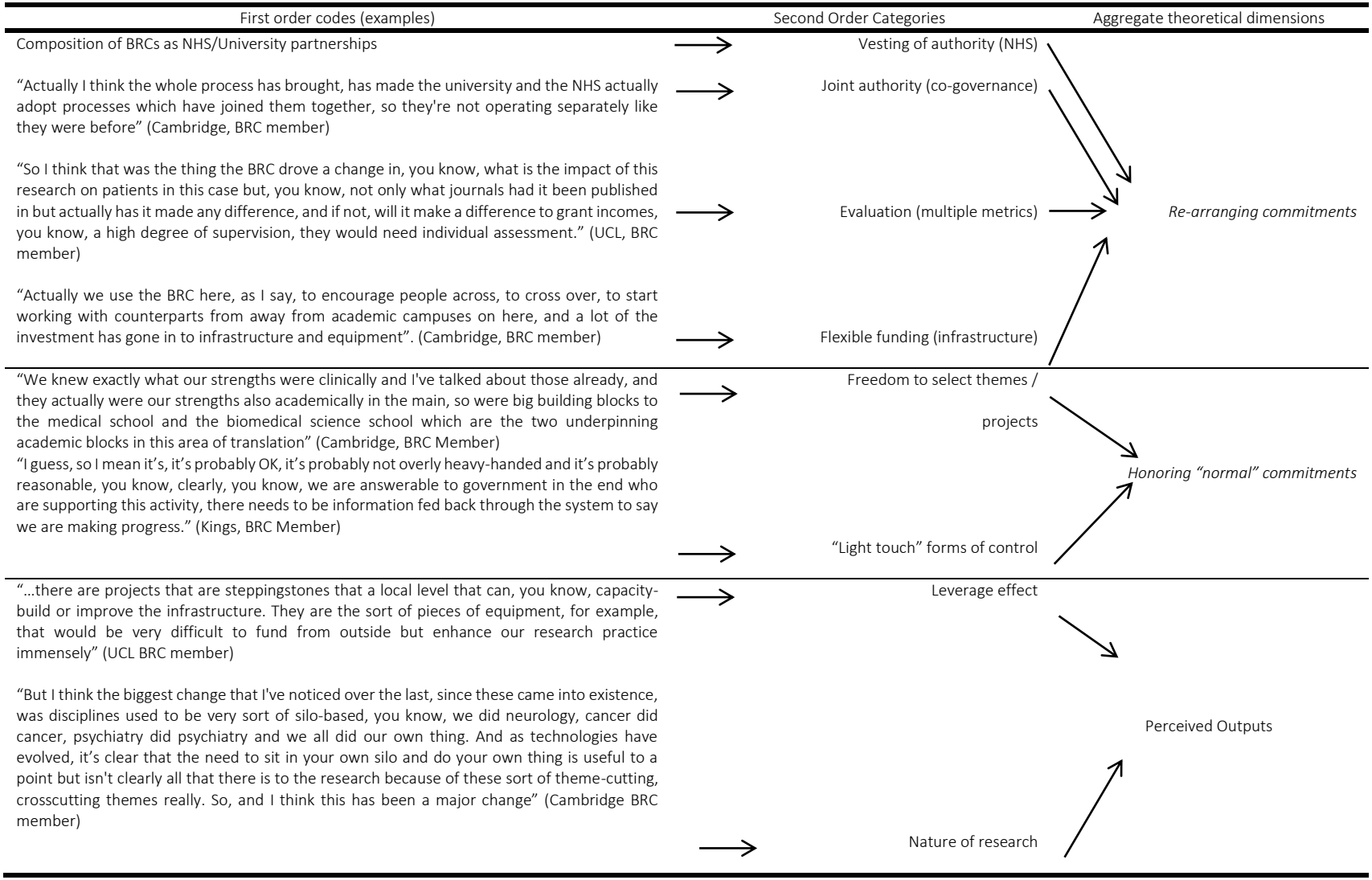


Table 4. Univariate comparison between treatment and control groups

		Pre-match		Post-match	
Variable	BRC leaders	Control group	Difference	Control group	Difference
Sex (male)	0,94	0,76	-0.17**	0,94	0.00
	(0.23)	(0.42)		(0.42)	
Dif first publication	23,11	19,73	-3.38**	21,62	-1.49
	(7.49)	(9.64)		(6.57)	
Av. no MeSH terms	3,97	3,56	-0.41**	3,96	-0.00
	(0.53)	(0.99)		(0.46)	
Av. no coauthors	6,07	5,13	-0.93**	5,99	-0.07
	(1.66)	(2.04)		(1.26)	
Av. annual papers published	10,29	5,13	-5.15**	7,81	-2.48*
	(7.31)	(5.12)		(4.98)	
Growth rate av. annual papers published$_{(t-6,t-1)}$	1,84	1,27	-0.57	1,41	-0.43
	(6.08)	(4.55)		(4.22)	
Growth rate self-proximity$_{(t-6,t-1)}$	-0,05	-0,02	0,02	-0,03	0,01
	(0.16)	(0.34)		(0.14)	
Growth rate self-proximity$_{(t-2,t-1)}$	-0,02	-0,01	0,01	-0,01	0,01
	(0.07)	(0.30)		(0.07)	
Growth rate paper novelty$_{(t-6,t-1)}$	0,03	0,03	-0.00	0,06	-0.02
	(0.29)	(0.42)		(0.28)	
Growth rate paper novelty$_{(t-2,t-1)}$	-0,01	0,00	0,01	0,00	0,02
	(0.25)	(0.42)		(0.20)	
Growth rate extreme paper novelty$_{(t-6,t-1)}$	-0,01	-0,01	-0.00	-0.00	0,01
	(0.12)	(0.22)		(0.22)	
Growth rate extreme paper novelty$_{(t-2,t-1)}$	-0,01	0,00	0,01	0,00	0,01
	(0.12)	(0.19)		(0.09)	

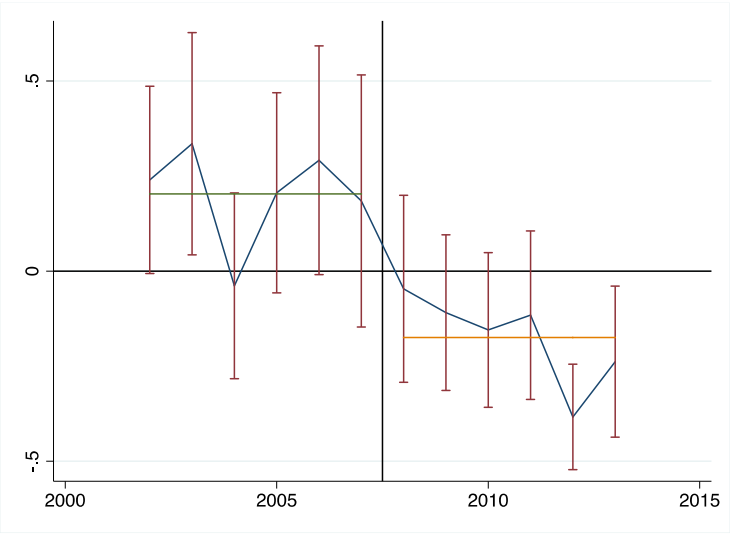
standard deviations in parentheses, † p ≤ 10%, * p ≤ 5%, ** p ≤1%

Table 5. Difference-in-Difference Tests

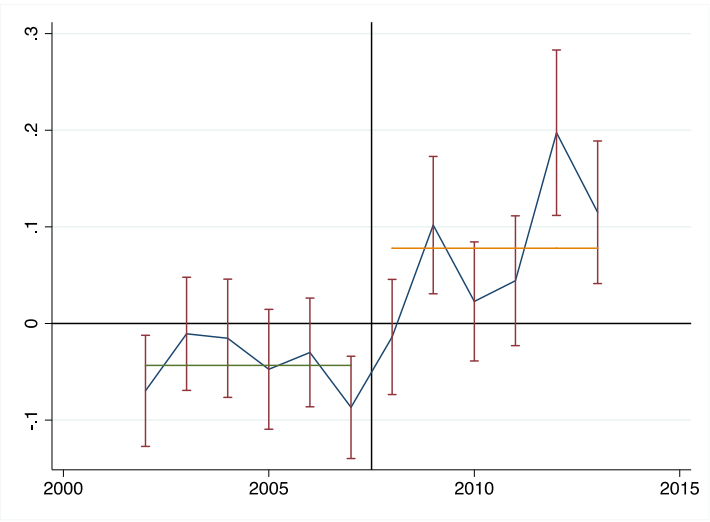
	Mean BRC leader difference (after - before)	Mean control difference (after - before)	Mean Dif-in-Dif estimator (BRC leader - control)	Dif-in-Dif estimator *t*-statistic
Self-proximity	-0,034	0,013	-0,048	-3.468**
	(0.009)	(0.010)	(0.014)	
Paper novelty	0,010	-0,048	0,058	2.12*
	(0.019)	(0.019)	(0.027)	
Extreme paper novelty	0,001	-0,027	0,028	2.36*
	(0.008)	(0.008)	(0.012)	

standard errors in parentheses, † p ≤ 10%, * p ≤ 5%, ** p ≤1%

Graph 1. Standardized differences in *self-proximity* between BRC leaders and control scientists, 2002-2013



Graph 2. Standardized differences in *paper novelty* between BRC leaders and control scientists, 2002-2013



Graph 3. Standardized differences in *extreme paper novelty* between BRC leaders and control scientists, 2002-2013