Power and networks in worldwide knowledge coordination: the case of global science

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Abstract

The article considers the global governance of knowledge systems, exploring concepts of power, networks, standards (defined as normative practices), and structuration. The focus is on science as a form of predominantly private global governance, particularly the self-regulatory and collaborative processes stretching across time and space. These constitute networks and are largely (and increasingly) outside the gaze of governments. Although science worldwide, but especially in the West, has been increasingly characterized by forms of scientific nationalism, in which science is funded, regulated and harnessed for national governmental ends, the article argues that the growth of the new communicative technologies and the rise of openness as an ontology in the digital age is facilitating global science as a more private sphere, one of sociability rather than sovereignty, and one that is characterized by loose ties and curiosity-driven scientific ambitions.

Key words: science; networks; power; standards; global; governance

Introduction

This article considers the global governance of knowledge systems, exploring concepts of power, networks, standards (defined as normative practices), and structuration (King, 2010; King, 2011; Stones, 2005). The focus is on science, which is defined as the systematic pursuit of knowledge through institutions or structured collections of norms, including publicly-recognized scientific organizations. That is, the term ‘institution’ is used to apply to norms, standards, and other normative ensembles whilst reserving the description ‘organization’ for particular entities. The focus is on the natural rather than the social sciences although similar processes may be at work in the latter, too. It is argued that the striking focus on science as increasingly connected to national and governmental objectives, especially worldwide economic and military competitiveness, in higher education research, government policymaking and the media in the last half century or more, tends to ignore the predominant and increasing characteristic of global science as a largely privately-governed, networked, and normatively self-regulating institution.

Moreover, this form of science is globalizing through expanding research collaborations across countries in ways that largely occur outside the control of governmental authorities. Citation and other publication indexes of scholarly research indicate a remorseless increase in global scientific collaboration. In March 2011, a Royal Society report, ‘Knowledge, networks and nations’, stated that over a third of all articles published in international journals are internationally collaborative compared to around a quarter only 15 years ago. Although telecommunications technology has been a major facilitator the Royal Society felt that the primary driver of most collaboration is individual scientists aiming to cooperate with the best of their peers (Royal Society, 2011).

Collaboration is largely curiosity-driven and reflects particularly the ambitions of individual scientists for reputation and recognition, not least as a means of pursuing their own research agendas. However, unlike the claims made for science as a benevolent coordinating community based on shared norms, by theorists such as Merton (1942/1996), for example, it is suggested here that global science is characterized by networks of enclosure and preferential attachment as well as openness, and that network power as well as coordination is a key feature. Moreover, the claim that the conditions for innovative science are necessarily based on national socio-political features, namely the liberal democratic open society (Merton, 1942/1996; Popper, 1945; Wagner, 2008; and Fukuyama, 2008), may be becoming less persuasive with globalization and the growing importance of largely private forms of worldwide scientific collaboration across a variety of state forms, which has been facilitated by the new communicative technology.

State and society in global science

The development of the ‘knowledge economy’ has seen many governments emphasize the importance of science and innovation as necessary for national competitiveness in an increasingly globally-connected world. In this perspective international scientific collaboration takes a different form to the ‘universal knowledge’ and ‘free science’, based on the open results and peer review, of an earlier age (notably the seventeenth and eighteenth centuries in Europe). Rather, as Peters (2010a, 230) remarks ‘this (older) liberal meta-narrative of science has been submerged by official narratives based on an economic logic linking science to national purpose, economic policy, and national science priorities’. Western control and bias still predominates in this emerging geography of scientific knowledge, not least as the growth of ‘big science’ and the rise of serious global issues that cut across territories, such as environmental despoilation, require both increased international collaboration promoted by governments and also heavy state funding.

As such, science worldwide, but especially in the West, has been characterized since the middle of the last century by increasing forms of governmental nationalism (that is, science is harnessed, and indeed increasingly regulated and ostensibly funded, in support of national policy goals such as military and economic competitiveness). The hundred years or more preceding the Second World War had seen European empires seek to apply science for medical, military and administrative advances in their newly-acquired territories (Ferguson 2011). These early infrastructures of ‘colonial science’ not only reflected colonial competition, however, but also established the beginnings of governmentally-driven and competitive global science. It was the ‘big science’ of the post-1945 years (expensive investment in basic science, particularly physics, for space and military research) that extended global governmental collaboration (although this was also partitioned by the rivalry of the Cold War years). The establishment in the 1950s of the European Laboratory for Particle Physics (CERN) in Geneva is an early example of cooperation between European governments, while the European Science Foundation that was formed in 1974 also sought a closer coordination of European science (Peters, 2010a, 239), as did the global scientific programs established by bodies such as UNESCO. The private corporate sector also played its part in the development of big science. Transnational corporations, especially biotech and pharmaceutical companies, sponsored international scientific collaboration, characterized less by openness, however, than commercial advantage protected by growing forms of intellectual property regulation. And, of course, in the last 20 years or more, global collaboration by not-for-profit entities such as universities and large-scale charities has expanded considerably.

As well as big national and commercial science, recent years have witnessed also the growth of open sources of knowledge and science. Peters (2010b, 248-9) describes a new ‘ontology of openness’ as ‘the economics of file sharing’ promotes new modes of collaboration and cooperation, not least as universities (such as Harvard) increasingly make available and free online their research articles. Here, we are beginning to see the idea, derived from previous eras, of science as a public good. It is a process that is not marked by simple altruism, however, but by the idea that scientists believe they innovate best when they collaborate across national borders and that this worldwide curiosity-driven (rather than state-driven) approach best serves their personal scientific ambitions. It is a process enormously aided by recent advances in communicative technology in recent years. This marks a move from scientific nationalism for most researchers to a stronger foundation of globally-networked and more individually-based science (Wagner, 2008).

Science as a network

Science’s normative system is distinguished by self-regulatory and collaborative processes that stretch across time and space. We may conceptualize these as *networks,* and these are largely outside the supervision of governments. Science is not alone in possessing such characteristics in the current global age. Prominent elements of globalization can be understood as the growth of shared forms of social coordination as the world reconstitutes itself around a series of networks – increasingly interlinked – that are strung around the globe on the basis of increasingly advanced communication technologies. A *network* refers to an interconnected group of people linked to one another in a way that makes them capable of beneficial collaboration (such as through the exchange of goods in markets, the exchange of ideas, or the possession of a common language). Standards and norms characterize the *way* such networks operate.

The concept of *structuration* is useful here to account for the actions that reproduce such social coordination. By *structuration* we refer to the interplay between agent and structure in the accomplishment of social practices, including the tensions between autonomy and constraint for agents (Giddens, 1995; Stones, 2005). The reproduction of social coordination is not simply a technical or neutral process but involves power – both as a form and consequence of individual decisionmaking but also as an aspect of wider social relations or structures (Grewal, 2008). Structuration, combining notions of both agent choice and structural constraint, enables us to understand, for example, how the actions of scientists call upon, are constrained by, and ultimately reproduce (not necessarily intentionally) the scientific normative practices we describe as *standards*.

Standards and network power

To understand global science as a powerful normative system with standards that help constitute and coordinate scientific practices worldwide, and where such standards are being constantly reproduced by such practices, requires that we regard global science as a constantly *emergent s*ocial system or social network. By emergent we mean that the system and its direction of travel is not centrally- or governmentally-planned but is the outcome of the many interdependent, individual, and decentralized normative decisions of scientists (Wagner, 2008).

The idea of a social network rests on the idea that individuals seek forms of cooperation and interaction with other individuals, involving reciprocity, and mutual expectations and adjustments, and these interactions are mediated by the standards that govern access to social networks. That is, to converse with other English speakers you need know and reproduce the grammatical and other rules of the English language. Such language rules are not centrally-policed but are self-regulated spontaneously by individuals through the act of speaking or writing English, and such language communication thereby continues the reproduction of the rules (syntax, grammar, and so on) governing the English language (although individuals may not have such a reproductive intention in mind when they converse in English). Therefore, the standards, rules, or norms of English are *inherent* to the practice of communicating in English (as are the rules for other languages). That is, without the standards there is no communication.

As Grewal (2008) has noted, however, some standards are not simply mediating or coordinating standards in this way; rather they are membership standards. That is, some notion of a standard or norm as an ideal or as an exemplar is at work. To join the network requires that you accept such standards even if they are not strictly necessary for operating within the network. For example, some scientific organizations may require from applicants a certain quotient of highlycited publications, although possession of such does not necessarily preclude the ability to perform according to the norms of global scientific networks. Often membership standards require formal policing or some similar kind of organizational scrutiny (unlike coordinating standards). In many cases, however, it is not always easy to distinguish between the two types of standards – coordinating and membership - as, in science for example, accepting conventional scientific practices is required to become a bona fide scientist (member of the network) as well as being able to practice as a scientist. That is, scientific norms act as both membership and coordinating standards. The key, however, is to see access to the network as the key objective, and to regard the acceptance of the network's standards as providing the means for coordinating with, for joining, a network.

In this sense, both membership and coordinating standards possess forms of power in networks. In the current global age especially, some networks appear more dominant than others and their standards consequently possess high levels of power – which is reinforced as such standards universalize. In such cases there seems no choice but to accept the standards of the network if you wish to gain access to it (especially if such a network is a highly-desired and powerful one). In globalization, as a result, many dominant standards appear coercive to us, entrapping as much as liberating, and appear as having been settled and agreed outside our influence, even though our ostensible free choices to accept such models in order to gain network access helps to maintain such networks. People seek to join dominant networks for access and not necessarily out of a belief in the inherent benefits of that network's standards for their own practices. They join because of others who are also members. They join, that is, for extrinsic rather than intrinsic reasons (Grewal, 2008).

Notions of *standards* and *network power* define the particular ways in which networked actors (such as scientists) are connected and constituted through norms as standards of appropriate behaviour. Although the notion of standards is often used technically or distinguished as a more formal template than norms, here we see s*tandards* more broadly as the behavioural norms that regulate the interactions of independent agents in the absence of formal hierarchy. In this sense they are an aspect of sociability rather than sovereignty (Grewal, 2008). Standards (although more diffuse and less technical in our interpretation) are similar to the protocols governing access to the Internet (or to the relations between diplomats, where the term was made widespread); they are necessary to enable people to interact with each other in the absence of formal hierarchy. Without such standards there is no network or communicative interaction. While actors are free to stay outside networks, those that do face marginalization. That is, power in networks tends to operate through social exclusion rather than hierarchical coercion.

As we have indicated, some norms, or standards, or models come to possess a powerful influence worldwide. In some cases they become effectively universalized, knocking out or dominating competing networks and normative standards. Examples include: current global accountancy standards; the Gold Standard as a means of regulating the value of currencies in the first half of the twentieth century; the English language, with all its localized variants, as the dominant commercial and cultural language of the current globalization; and, in higher education, many of the practices associated with neo-liberalism and so-called 'New Public Management'.

Why do some standards or models become so dominant? This takes us to David Grewal's notion of 'network power'. *Network power* characterizes the 'pulling' power of universalizing or dominant models or standards (Grewal, 2008). That is, some norms may reach levels of adoption by a critical mass of actors, particularly in the global age, such that a 'tipping point' is reached and widespread agreement to follow by current non-adopters quickly ensues. However, although the notion of the 'snowballing' of adoption is used suggestively by some (such as Finnemore and Sikkink, 1999) to refer to the almost involuntary nature of such adoption, we need to be careful to avoid a sense of structural determinism as all such processes do involve formally free individual choice-making. Furthermore, explanations for the dynamics of a rapidly-diffusing model require conceptualizations of power in networks; networks are not formed simply in response to coordination problems and nor are universalizing models taken-on purely as a result of superior technical qualities.

<u>Worldwide social cooperation</u>

Structures, such as standards and similar normative frames, help to constitute the social cooperation worldwide made possible by the technological and communicative compression of space over recent decades. This magnetizing or ‘pulling’ effect for a powerful model gathers pace once a certain critical mass has been reached of network participants coming to share the defined norms of practice (standards) associated with a particular model. After such a threshold of adoption has been reached, the ‘spread’ of universalizing standards to previous non-adopters may be as much for extrinsic reasons (the sheer weight and/or influence of the network’s users) as for intrinsic judgments (the merits of a particular standard). As with telecommunication networks, the more users a network possesses, the more attractive it becomes to potential users in comparison with competing systems.

While individuals, including policymakers, ontologically (formally) are always ‘free’ to choose to act other than the way they do, in reality they frequently feel that they have few, if any, options. Although the power of structures is not necessarily experienced in an oppressive way by agents (even though regarded as exercising a form of dominance), certain models are able to settle the terms of access to important global networks in a manner that seems outside the direct influence of those participating, or wishing to participate, in such networks (Grewal, 2008). Science provides a good example.

<u>Global science</u>

The sociologist Robert Merton (1942/96) famously was among the first to investigate science predominantly as a social institution. That is, science involves recognized methods and accumulated knowledge but above all it is comprised of interacting individuals and networks reproducing norms and standards. These norms appear in the form of principles for what is allowed and what is not, and as rules for what actions and procedures are desirable and which are to be discarded. These become legitimized in institutional values. That is, scientists form a moral community with an agreed outlook as to appropriate behaviour.

Particular types of (macro) social structure are more conducive to world-class science than others in this view. Specifically Merton asserts that the conditions of individual freedom, institutional autonomy, and scientific and other forms of pluralistic self-regulation that constitute key value systems in liberal democracies, are functional for producing high-quality science. The market as well as the state, if both become overly-intrusive and prescriptive, can threaten the ideal of normative self-regulation. The role for commercialized ‘intellectual property’ is quite limited here. Rather, secrecy and non-public disclosure potentially violates the scientific norm of openness which sustains the pursuit by individual scientists of reputation and esteem through their wide and timely dissemination of findings. These views have come to assert a powerful hold on scientists globally and help to mediate scientific coordination on a wide scale. Nonetheless, unlike Merton's emphasis, we note also that scientific standards and networks do not simply coordinate and self-regulate researcher communities, they also may solidify existing hierarchies or 'preferential attachments' through forms which reflect Western advantage and control.

Undoubtedly global science is based on a universalizing set of standards that mediates the social coordination of scientists worldwide. This both constrains and facilitates researchers seeking access to the network of research and collaboration that is constituted by such normative frames (King, 2011). Scientific norms display what Giddens (1995) famously has described as the 'duality of structure'. They are both the medium (the means) and the outcome of research practices. In producing valued research outcomes by using accepted scientific conventions, an individual also contributes to that structure's reproduction through time and space (although unintended consequences of course may also follow and be a source of change).

Scientists in their investigative practices draw upon, and thereby reproduce, not necessarily intentionally, the globalizing rules and resources associated with scientific standards. Convergence on global research standards is therefore created and reproduced through an accumulation of many decentralized and individual choices. While these decisions are made autonomously they are also strongly-constrained, reflecting the power of scientific networks and scientific standards to influence such choice-making.

<u>Scientific governance as sociability rather than sovereignty</u>

Global science occurs largely behind the back of the nation state, despite powerful political rhetoric espousing the competitive economic necessity of scientific nationalism in the knowledge economy. The standards and conventions of science provide a form of globalization through their facilitation of worldwide communication and cooperation by scientists. Dominant scientific models exert a powerful pull on researchers who seek access to the forms of worldwide research cooperation mediated by such structures.

We should note, however, that levels of exclusivity in science nonetheless do not appear particularly weakened by global ties. Classifications, such as global university rankings and disciplinary reputations, re-assert and bound traditional research standings, in higher education at least, in this period of considerable diversity in scientific locales and knowledge explosion. Resources and relationships appear to be subject to forms of cumulative inequality and preferential attachment that benefit elite scientists through traditional processes of reproductive hierarchy (Wagner, 2008).

Scientific authority is thus determined by the mutual, self-regulatory association of scientists. Professional standards provide the focal points to enable the social coordination of autonomous and interdependent agents to form the most efficient and effective organization of science (paralleling similar processes found in capitalist markets). Although scientific work is conservative in that its methods and integrity with established knowledge are principles adhered to strongly by scientists, the demands for originality spearheaded by reputation-enhancing individual researchers enables science also to be progressive and vital (Philips, 2007). The dynamic in the system of scientific social reproduction, accomplished through autonomous actors drawing upon and thus reproducing existing standards and resources in forming their social practices, is the individual motivation for reputation and esteem that comes from producing path-breaking discovery. Rather than portraying science within a model of static functionalism, science as a social institution always requires the energy and innovation that comes from ambitious and career-enhancing researchers.

Networks of collaborating peer-related strangers rather than those characterized by close, longstanding, and immediate association appear to innovate most when it comes to generation of the ideas and similar intellectual assets found in the knowledge society. Weak ties, not least those found over the relatively anonymous Internet, bring new and more ‘chaotic’ knowledge with little of the high-maintenance social baggage found in closer relationships (Granovetter, 1973). Loose-tie networks are less insular and distrustful of new ideas and strangers than the more intense social and locally-based communities that tend to exhibit high levels of normative uniformity.

Yet, even weak-tie networks require some levels of 'working social capital' in the form of trust and expectations of appropriate behaviour, including, in science, adherence to the values of the scientific community. But it is a normative trust founded on professional rather than close-knit social relationships. Interaction is based more on a periodic sharing of the excitement of intellectual dialogue and discussions than through the social intensity of more integrated relationships. 'Weak-tie' relationships or networks are not market-based or bureaucratically-commanded but rather take the form of voluntary collective action.

Global science is increasingly characterized by the technologically-aided collaboration of researchers over vast distances who share weak ties that leave them relatively free to focus on scientific productivity around a specified project or series of projects. Nonetheless, this transnational cooperation requires standards, conventions, and rules. Scientists look for ways to access important scientific networks in the absence of global sovereignty. Their social coordination requires frames of reference – standards – to facilitate exchange. Increasingly, certain standards of the scientific community have assumed a dominance that confronts individual researchers. They exercise a form of network power that is not easily shrugged aside if access to critical scientific resources and researchers is desired. The choice whether to accept powerful network standards or not – and autonomous agents have free if increasingly involuntary choices on these matters – may be between access to the global scientific community or exclusion from it.

Although science networks reinforce the idea of global governance more generally as containing strong elements of private or self-regulatory authority, and although patterns of coordination are largely non-governmental, neither are they random. They follow clearly recognizable patterns and rules and are based on normative association. That is, tacit modes of social coordination are achieved through standards that exercise closure and network power.

Moreover, quite long processes of scientific apprenticeship, qualification-building, and inter-personal contacts help to develop this tacit knowledge which is necessary for scientific understanding. Without the reflexively-generated and generally unstated knowledge that is constituted within sciences' 'invisible colleges' (Wagner, 2008), it becomes difficult for outsiders to replicate experimentation by following published and formally-codified processes alone.

Globally networked science, despite becoming more publicly-accessible than before, is not necessarily a model for the ‘open society’. It operates by rules which, although not controlled by any specific organization or state agency, are not easily perceived by outsiders. As Kealey (2009) and Wagner (2008) note, the expense of forming a transnational research network can be large and participation can be costly. Participants must share valued information or provide another resource – funds or experience, for example – and as a network matures the cost to new members rises accordingly. Moreover there is a distinct system of cumulative inequality at work. Those that have high reputations, extensive collaborators, many citations, and relatively easy access to research funds and to the most talented younger scientists, tend to attract even more. A law of ‘preferential attachment’ appears to operate in which highly-creative and productive people attract other such individuals (Florida, 2008: 64). The global science network operates with, at best, limited openness.

Of course, much of this would have been familiar to Merton and even applauded. That is, cumulative advantage and levels of exclusivity could be justified within the terms of the open society as continuously changing its composition and reflecting always temporary outcomes that are quickly challenged by the relatively open competition, merit, and reasonable equality of opportunities found in scientific communities. Yet normative processes may be as ‘closed’ to outsiders as are state power and commercial markets, and may not be quite as illustrative of meritocracy as Merton and others assumed.

Second, contemporary notions of academic freedom and university autonomy are somewhat ambiguous in many countries, not least in liberal democracies where NPM has come to predominate as a mode of control and external accountability. Marginson (2008) suggests that NPM is not necessarily incompatible with academic freedom as a whole as it involves heightened senses of individual freedom from sometimes stiffly professorial and similar collegiate influences, although it does increase external control, accountability, and agenda-setting (commercially and by public agencies). Moreover, governmental and even some commercially-specified research priorities and funding for universities still tend to be accompanied by conventional mechanisms of allocation based on peer review and academic excellence.

Nonetheless, academic autonomy and entrepreneurialism sit uneasily alongside external accountability and recent state strategies for funding research. University researchers feel that research agendas have become increasingly externally-controlled, diminishing the creativity and serendipity they regard as essential for high-quality basic science.

Global science's networks and standards

Emergent global science, however, enhances the opportunities for researchers to undertake collaborative projects across territorial boundaries outside the direct control of national governments. A feature of global forms of governance is often their private and self-regulatory nature. In science, global networks and their associated processes of standardization have begun to exceed the power of governmental scientific nationalism. While the latter regards scientific outcomes as national assets to benefit a country's economic and military objectives, global science is characterized by a self-governing and self-reproducing form of coordination that is highly unequal in its national consequences. It has developed strongly in the last two decades or so, not least with the ending of the Cold War between the USA and the Soviet Union (including their respective allies) and the widespread communicative use of the Internet.

The use of network theory as a framework for gaining insights into the essentially self-regulating world of twenty-first century science has been well exemplified by Caroline Wagner in her work *The New Invisible College: Science for Development* (2008). She suggests that in the sixteenth and seventeenth centuries as well as now, scientific coordination and discovery are characterized by scientists exchanging ideas as part of a shared search for knowledge. However, in the current age, networks have a technical dimension (the World Wide Web) as well as a social one. Moreover, government exercises less control over science now than a few decades ago, when high- cost 'big science' dominated. Rather, a renewed and networked model of science into the current century is a more open system and based on individual collaboration.

A preponderance of worldwide scientific joint ventures is formed by person-to-person projects rather than by trans-ministerial agreement. Mainly these are arranged collectively by individuals through well-established professional and disciplinary linkages. The objective is to create a research project of discovery founded on complementary capabilities and shared curiosities. Finance, however, is usually derived from national and similar public funding agencies that are unable or unwilling to exercise too strong a constraint on who is enrolled to work on the project, especially when elite scientists are involved, once projects have been approved. National priorities set by governments also appear to aid networked global science of a more informal kind in that national research and innovation agendas display a remarkable convergence around a few areas, such as biochemistry, nanotechnology, genetics, and the environment, rather than reflecting local concerns and circumstances, thus facilitating worldwide scientific 'clustering'.

One interpretation of these developments is to argue that the necessary affinity between high-quality science and the open society associated with liberal democracy has taken a globalized turn. Fukuyama (2008, 1-2), for example, maintains that most research in basic science 'can develop only in an atmosphere of free and open exchange' and that this helps to explain the strong internationalization of scientific collaboration in recent years. Despite governmental rhetoric (and funding) that views science through a national prism, underpinned by strong beliefs connecting scientific development to national wellbeing, globalizing science 'can be understood only as the by-product of a horizontal process of social collaboration in which merit and results trump any consideration of national origin or jurisdiction' and whose outcomes are largely public rather than proprietary goods. Modern science is thus an emergent transnational system (it reproduces itself through the interdependence of countless individual actions rather than by sovereign direction). It generates complexity in an unplanned and unpredictable way through the interactions of autonomous agents.

Wagner (2008, 1) provides considerable evidence to support the view that the focus of science has moved from the national to global level and that 'self-organizing networks that span the globe are the most notable feature of science today'. Scientists are collaborating across the globe not because they are ordered by governments to do so but because this is often the best way to utilize differing perspectives, resources, and knowledge to conduct the high-quality science that satisfies both individual curiosity and the career desire for esteem, reputation, and also scientific autonomy.

Such a picture contrasts sharply with the dominant paradigm for knowledge and innovation in most of the advanced countries in the second-half of the twentieth century, which Wagner terms ‘scientific nationalism’ and where science is conceived as both governmental and national property. In the USA, Europe, and Japan large federal and regional agencies came into existence after 1945 to manage the relationship between the scientific and political communities. Publicly-funded programs to help the economic application of scientific results also developed. The scientifically-advanced countries contributed to scientific governance by introducing regulations, standards, funds, and institutions to develop and capture the advantages of science. Wagner (2008, 23) notes that ‘science, technology and state institutions co-evolved into mutually helpful entities’. Even now the connectivity between national sciences and governmental technology policies remains a highly observable element of the system of science worldwide.

The recent movement to a globally-based, networked science is controlled effectively by researchers rather than by governments. Even the recently formed European Research Council lays heavy emphasis on practitioner rather than political or bureaucratic objectives-setting. Global science is self-reproducing in that its structure is formed by interacting and communicative researchers who use such structures as the basis for their own action as autonomous agents and who, through their scientific collaborations founded on worldwide views as to the ‘morality’ of science and its methods and conventions, thereby simultaneously sustain such structures. The global alliances of scientists, like university league tables, provide reputational and informational shortcuts within a world of exploding knowledge and potential contacts. They are ‘status-signaling’ devices, creating a basis of trust that facilitates confidence in exchanging information on the foundation of common norms.

Global science is thus both open and bounded. Reputation provides a heuristic to ‘order’ rapidly growing knowledge, and disciplinary and institutional rankings help do this by reinforcing existing worldwide patterns of scientific opportunity and inequality. Although scientific networks remain collegiate, insider-understood, and protected (Kealey, 2009; Wagner, 2008), and while obscure processes and the high levels of tacit knowledge found in scientific experimentation and outputs continue to maintain strongly exclusionary tendencies, these are not the only mediating characteristics. Strong notions of autonomy, objectivity, testability, and peer judgment provide key standardizing features across the global scientific network. Moreover, not only do scientific normative models provide ‘ordering’ and coordination across researchers’ networks, they also operate as forms of power.

Networks

As we have noted the network of global science has been described as ‘emergent’ in that, rather like an ecosystem, it develops unpredictably on the basis of free individual exchanges (Wagner, 2008). In our conceptualization, actor exchanges freely entered into are subject to processes of structuration in which actors use and maintain (and modify) structures through their decisions that in turn both enable (constitute) and constrain their actions. Scientific structuration involves the utilization and reproduction of key standards and these characterize the particular manner in which the members of scientific networks are interconnected. These standards are comprised of shared norms of practice which enable members to gain access to each other and to generate cooperation (Grewal, 2008).

Such standards serve to coordinate the network, including through notions of correct operational methods, but they also act as entry or membership tests for the network. That is, their acceptance as mediating standards is a requirement for accessing the network itself. While membership standards more generally may require explicit collective regulation and policing by a network, mediating standards in science tend to be tacit and individually self-enforcing.

In the same way that we use language – its grammar, vocabulary, and rules – as a resource to communicate with fellow language speakers (or through a process of translation into another language with similarly understandable rules), and thus, through our utterances and actions, contribute to the language’s continued reproduction across time and space, so scientists use scientific standards as a medium of social coordination and, by doing so, through their practices contribute to the reproduction of these standards. Changes to standards clearly do occur, in some cases as a result of exogenous factors outside the scientific world, such as governmental or economic actions, and, in others, as endogenous or internally-created adaptations. More especially change occurs as a result of strategizing by actors in the context of differential power resources associated with dominant network standards.

Conceptualizing networks

Global science networks may best be described as '*networks-as-structures*'. In this conception, relational structures in a network systematically influence the actions of its members and generate recognizable outcomes. That is, network structure is an existing resource for actors and is reproduced by decentralized and autonomous agent choicemaking in social practices. Thus, although created by agents' decision-making, network structure is not the deliberate result of conscious and purposeful action designed to produce such a goal. Rather the focus of our interest is on the *effects* of such networks – as structures and resources – for the individual actors and groups who comprise them.

An alternative perspective is to conceptualize '*networks-as-actors'*, which does refer to deliberative collective action in order to achieve particular objectives (Kahler, 2009). Often operating to influence governments, *networks-as-actors* are political entities frequently found within the sphere of sovereignty, while *networks-as-structures* turn our attention more to processes of sociability.

Both network concepts – as structures and as purposeful actors – tend to become intermingled in concrete situations: networks tend to normatively constrain actors as well as forming the basis for collective associations to take up the cudgels to promote the ideas and interests of members. Yet both refer to rather distinctive notions of power. '*Network power'* flows from *networks-as-structures*, while '*networking power'* reflects the purposeful actions of the network as a collective agent, or *network-as-actor* (Kahler, 2009). Global science is characterized especially by '*network power'* and by standards that impact strongly on individual agents. More particularly, the spreading network power of scientific models is aided by quite high levels of their incompatibility with any alternative scientific standards. Such incompatibility tends to drive the dominance of already powerful networks governed by distinctive norms of practice and moves towards the universalization of a single model. The network's size is progressively increased and leads to the decline of alternatives. As with telecommunication networks, the more members or subscribers to a increasingly dominant network reduces the efficacy of alternatives and raises the relative cost of other competing (and weakening) networks to users.

Scientists (and proto-scientists) experience global science as a given structure which shapes their behaviour – and it is also the outcome of the actions of scientists. This structure is comprised of standards, including 'scientific methods' that as they stretch over time and space attract '*network power'* properties based on global normative influence. Alternative models and networks (such as those found in 'totalitarian' societies characterized by state-withering constraints over individual and institutional autonomy, in the name, say, of advancing overriding political objectives) increasingly lack credibility and influence. That is, they lack power as standards (Grewal, 2008).

'*Networking power'*, however, in contrast to the '*network power'* associated with models and standards and which is largely structural, attaches more to individual agents – to scientific 'stars' – through such processes as 'preferential attachment' and cumulative advantage. Here new members (doctoral and postdoctoral students, for example) disproportionally attach to individuals (network nodes) that are already densely connected to other nodes. As Kahler (2009) and Wagner (2008) respectively note, global science is a scale-free network in which connections exhibit a power-law distribution so that a large number of scientists possess few network links while a small number display many.

Generally network forms of organization allow actors to maintain their freedoms (they allow exit options) and this is perceived as highly desirable by scientists who value their intellectual freedom (although a consequence of exercising the exit option may lead to marginalization in global science). Moreover, scientific autonomy and creativity are furthered enhanced by the 'distant' connections between practitioners that characterize global science and creative innovation more generally.

Conclusion

Dominant models of many sorts generally do not exist in a vacuum. They impact, sometimes negatively, on other policy objectives. NPM and associated commercialization approaches to research for example, despite facilitating increased enterprise, may encourage short-termism and limit the scope for scientific curiosity and creativity in basic research that are essential for high-quality innovation (OECD, 2008). Moreover, the growing production of world-class research in the natural sciences and engineering in China and other East

Asian societies suggests that socio-political constraints (the absence of key liberal democratic institutions) may be less of a hindrance in these disciplines (and capable of being overcome by heavy governmental funding) than in, say, the social sciences. China has increased its funding on research by six times in the last decade and has more than doubled the number of its scientists. Its output of scientific papers annually and its supercomputing capability is only bettered by the United States, although its international citations are only slowly growing (Ferguson, 2011, 318).

More particularly, the increased ability of scientists to collaborate across socio-political national borders and in the terms of the global scientific community as a self-regulating normative community, may be lessening any relationship between national political conditions and research innovation and cooperation as perceived by Merton, Popper, Fukuyama and others. The result may be that few if any constraints prevent centrally-driven states, such as China, from possessing world-class science or reduce their long-term ability to emerge at the top of global university and other research rankings. But for policymakers in a variety of state forms, a key issue is to find appropriate and effective means for steering networks of scientists in ways that facilitate national purposes but which do not dampen the creativity and autonomy that researchers require to innovate successfully and whose activities increasingly stretch across, and largely ignore, territorial boundaries.

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