Polycentric Governance

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Abstract

This chapter explores the relevance of polycentric governance – an approach whereby multiple, physically adjacent jurisdictions negotiate rules and policies to solve common problems – for managing converging knowledge, technologies, and society (CKTS). We trace the concept's origins, its advantages and challenges, and how the latter might be surmounted. By offering a means for innovative and improvised collaboration, multiple access points for monitoring problems and reducing risks, and inclusive decision-making approaches, polycentric governance provides a valuable framework for CKTS management. However, traditional divisions of labor among intellectual disciplines – as well as other impediments – will require that adjustments be made to permit shared approaches to intellectual work, enhanced means of communication among protagonists, and achievement of common, collective goals that benefit large groups of collaborators and society as a whole – as opposed to merely satisfying the needs of individual CKTS entrepreneurs or investigators.

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Introduction

This chapter examines polycentric governance as an approach to managing the ethical, legal, and social impacts of converging knowledge, technologies, and society (CKTS). Polycentric governance entails multiple, formally independent, spatially proximate jurisdictions ordering their working relationships through a system of negotiated rules in order to solve common problems more efficiently (Araral and Hartley 2013). Its advocates contend that these jurisdictions are in the best position to gauge the most effective means to address these problems in ways befitting their scope and complexity. Solutions may involve working through existing public authorities or establishing new entities with the power to impose fees or levy taxes (McGinnis 2005).

The concept of polycentric governance originated in observations of how locally incorporated communities, typically found in the US metropolitan areas, improvise solutions to cross-jurisdictional problems through contractual agreements. Subsequent studies examined the use of polycentric governance in managing "common-pool" resources such as freshwater, fisheries, and forests and implementing public safety programs in the entire regions (Ostrom 2010; Ostrom et al. 1961).

How is polycentric governance relevant to CKTS? While CKTS comprises products and services derived from intellectual exchange and RD&D, groups engaged in its work aspire to equitably share the benefits and costs of activities affecting each of them while also reducing potential risks that could befall any or all of them – as is true in these other policy domains. We begin with an overview of polycentric governance – its appeal and purported advantages as a governance vehicle for CKTS. We then turn to major challenges facing its application and how they might be overcome. We conclude by discussing future research needs we believe must be satisfied in order to make polycentric governance into an effective approach for CKTS issues. The technologies that comprise our focus include – but are not limited to – nanotechnology, biotechnology, information technology, and other fields based on cognitive science.

The Appeal of Polycentric Governance for CKTS: Advantages

Polycentric governance is an appealing management approach for CKTS for three major reasons. First, the rapid growth of CKTS has raised expectations in many corners that its potential for furthering economic innovation, enhancing environmental sustainability, and fostering improvements in the quality of life (e.g., by creating new jobs, heightening the competitiveness of various enterprises, broadening new energy options, and furthering human longevity and mental and physical health) hinges, most of all, on enabling its protagonists to work more closely together. Through close collaboration, CKTS proponents contend, barriers to innovation can be better identified, and means to efficiently overcome them – without unnecessary duplication of effort – can be developed. One oft-cited vehicle for such cooperation is referred to as a "convergence ecosystem" (Roco et al. 2013).

Convergence ecosystems are networks of actors who collaborate through institutional innovations that permit the free movement and exchange of ideas on a peer-to-peer level in order to generate sustainable innovation while also helping to being new CKTS ideas to viable fruition and practical, commercial application. Entities such as the Semiconductor Research Corporation, Silicon Valley, and various regional science and technology initiatives in the United States and abroad are often cited as examples of convergence ecosystems (Roco et al. 2013).

More to the point, convergence ecosystems display distinct *polycentric governance* characteristics in two explicit respects. First, they are improvised collaborations based on negotiated rules of exchange and governance regarding, for instance, how patents and licenses will be established and comanaged and how costs – as well as earnings – may be shared between partners. Secondly, they entail collaboration among spatially proximate actors committed to hastening innovation through geographically defined partnerships – possibly through developing a conjoint, physical research park or regional coordinating platform comprised of a wide range of academic and entrepreneurial partners (e.g., universities, corporations, investors).

A second reason for the appeal of polycentric governance among CKTS proponents is the wide bandwidth of uncertainties and possible risks associated with CKTS and the perceived need for some type of collaborative mechanism to manage these risks in ways that engender wide public trust and confidence. Using biotechnology as one example, some oft-discussed risks include the unknown environmental impacts of genetically altered or manipulated flora and fauna and the molecular-level effects of new pharmacological products or treatment procedures (e.g., stem cells). One question that has directly emerged out of such concerns is: how to regulate daunting, if unknown, risks of CKTS on one hand while using investment and other strategies to promote its further development in ethically suitable, socially beneficial ways on the other?

Because polycentric governance features multiple, relatively independent centers of power, there is greater opportunity for locally appropriate institutions to tightly monitor developments within a policy area – including emerging risks or hazards – and to introduce locally accessible, trustworthy approaches to their mitigation. Moreover, polycentric governance advocates claim, such local monitoring affords effective early warning, "safe-to-fail" interventions (in other words, policies that – should they not prove immediately effective in reducing risks – can be quickly replaced by newer, more adaptive innovations). In addition, by encouraging open communication and deliberation to build trust and shared understanding among diverse stakeholders, polycentric governance creates opportunities for social learning in places and scales that better match the spatial context of problems (Lebel et al. 2006). While this has been observed to be true in cases of resource governance in various countries, the evidence at least suggests that it also should be true in other policy areas where the desire to bring together subject-matter experts as well as lay audiences concerned with the management of the social and environmental impacts and trade-offs of a policy domain (Lebel et al. 2006).

Finally, with respect to risk management, polycentric governance approaches seek to bring together all the actors, rules, conventions, processes, and mechanisms concerned with how relevant information on risks is collected, analyzed, communicated, and, most importantly, conjointly managed (Renn and Roco 2006). It generally does so, if resource management and related experiences are reliable guides, by providing a platform for public-private partnerships and better incorporation of social science expertise to build public trust and confidence – and not merely wide-scale stakeholder participation for its own sake (Smith and Stirling 2010).

A third and final appeal of polycentric governance for CKTS revolves around a series of unique collaborative challenges that require special effort to overcome. These include the need for knowledge developers to be able to systematically straddle disciplines (cross-disciplinary collaboration is intrinsic to CKTS – less so for innovation within individual scientific domains). It also includes the capacity for technology innovators to go beyond ad hoc or coincidental collaborations that sometimes result in successful innovations, by exploiting the advantages of social networking media with regard to permitting the so-called leaderless movements of partners and associates.

While a number of virtual communities of scholars have emerged to share information about CKTS, thus far governance activities have largely been confined to research on public engagement strategies and their efficacy, as well as conferences that have been convened to discuss ways to better embrace public participation, understand the organizational dynamics of research, and the ethical concerns of CKTS as expressed by some decision-makers (Scholl et al. 2012). In this vein, polycentric governance may afford a platform for broader collaborations and discussions, as well as efforts to codify and standardize certain practices and adopt "best management" approaches for managing risk, fostering innovation, and encouraging effective engagement of all stakeholders. Let us examine these claims in greater detail.

In short, polycentric governance's major features dovetail closely with CKTS needs. Where CKTS aspires to promote "convergence ecosystems" to permit seamless collaboration in technology innovation, polycentric governance promotes ad hoc institutional arrangements that permit bottom-up, multiple-actor governance through the sharing investment of opportunities and cooperative use of physical as well as virtual intellectual "space."

Moreover, just as CKTS faces concerns regarding the management of risk through incorporation of participatory mechanisms, social science knowledge about public apprehensions, and social networking to permit rapid dissemination of information regarding both risks and benefits, polycentric governance acknowledges the importance of facilitating the collaborative work of different actors within a locally accessible institutional framework that enjoys a high-level of legitimacy, access to information regarding local conditions, and the capacity to adapt to changing conditions and opportunities expediently (McGinnis 2005; Hammond et al. 1999). As in any innovative governance arrangement, however, the challenges in achieving these objectives are as compelling as the purported advantages.

Challenges to Polycentrism: Fitting Governance to the Problem

A number of issues must be confronted in order to optimally fit polycentric governance to the management of CKTS problems. These include (1) investing in appropriate governance innovations that permit durable decision-making frameworks and information sharing – particularly regarding potential risks, (2) developing social media and telecommunications to connect stakeholders, and (3) facilitating meaningful public participation mechanisms, including facilitating dialogue and permitting direct engagement by the public in governance.

To make polycentric governance workable for CKTS, flexible, bottom-up decision-making is required. These include arrangements for building consensus among a broad range of stakeholders and deliberative interests. This requires a significant investment in the so-called risk governance frameworks – a particular type of polycentric governance innovation that has begun to emerge in biomedical and related fields. Risk governance frameworks seek to encompass the totality of actors, rules, conventions, processes, and mechanisms concerned with relevant risk information and associated data about CKTS consequences and impacts (e.g., Renn and Roco 2006). It is widely believed, in fact, that the successful dissemination of CKTS will depend, to a high degree, on the ability of risk governance methods to become adopted at the advent of new technological projects and involve the public, key stakeholders, and social scientists from the very beginning (Roco et al. 2013).

Recent experimental work on risk governance and public engagement in CKTS (Fleischer et al. 2012a) offers instructive lessons on the challenge of bottom-up decision-making and consensus building in polycentric governance. The European Union is currently focused on how to mitigate the potential risks posed by nanomaterials and their derivative nanoparticles – as found in laboratory – and emerging manufacturing-scale enterprises. There is currently a broad division of opinion regarding how to regulate these potential risks. One position, wedded to a strict interpretation of the so-called precautionary principle, would place nanomaterials under general suspicion "because of their new properties and the limited knowledge about their (potential) environmental, health, and safety implications." Advocates of this view propose broad, strong, and open-ended measures aimed at supervising and controlling nanomaterial development and introduction. A second position, closely linked to evidence from toxicological, ecotoxicological, and biological research and mainly voiced by manufacturers, supports largely voluntary measures for the safe handling of nanomaterials (Fleischer et al. 2012b), and, even in these instances, only those nanomaterials that give rise to palpable concerns should be regulated.

In an effort to experimentally determine how consensus that spans such divergent positions might be formulated through polycentric governance, researchers in the EU employed a series of focus groups comprised of laypersons who took part in a "deliberative test exercise" (Fleischer et al. 2012a, p. 84). Investigators learned that, while the results in and of themselves did not delineate specific governance strategies, they did reveal much about participant

perceptions of the appropriate roles of various protagonists in any governance system.

Focus group participants reposed considerable trust in the capacity of both governments and consumer organizations to properly oversee and, if needed, regulate developments in products containing nanoparticles. They were willing to give "a credit of trust, a leap of faith to these institutions," but they also wanted to be fully informed of potential risks of nanoparticles and products containing them in order to make informed choices (Fleischer et al. 2012a, p. 92).

For polycentric governance, three lessons emerge from this experiment relevant for CKTS. First, if one seriously contemplates instituting a risk governance framework for, say, nanotechnologies, it might be useful to have a *national database* of risk governance experiences in comparable – if different – topical areas (e.g., stem cell research, life span-increasing medical approaches) from which guidelines and best management approaches may be drawn. Such an investment provides an infrastructure of experiences that facilitates cooperation across jurisdictions and among groups by offering a common, proven set of methods can be selected – making collaboration easier and allowing protagonists to focus on implementation as opposed to laborious policy identification.

Second, and related to the first, some kind of a portal or repository to collect, disseminate, and most importantly *translate* CKTS information is needed. Such a repository would permit rapid assessment and management of risks and their consequences – particularly by manufacturers and consumers – by ensuring that nonexperts have information in a useful, useable form in order to make reasoned judgments and participate in CKTS governance (Graham 2002). Sometimes referred to as "coproduced" knowledge (i.e., information that synthesizes the scientific basis of CKTS with its societal implications), examples could include unbiased testing and evaluation results and readily available information on possible health and environmental consequences of CKTS. This abovementioned portal or repository would likely have two other responsibilities: (1) providing reliable and judicious means to protect proprietary and national security information related to CKTS and (2) assuring that CKTS information has been thoroughly vetted by several government agencies. According to Araral and Hartley (2013), two students of polycentric governance, such coproduced and translated knowledge is an important element to face the "crucial pathologies" of lack of accountability and information asymmetry, both of which erode public trust and confidence.

Social media and other information technology (IT) are also critical to making polycentric governance workable in the CKTS context. There is considerable debate in the literature regarding the degree to which telecommunication and social media enhance, or deter, inclusive decision-making on CKTS-related issues (e.g., Kamarck and Nye 2002). There is widespread agreement regarding two major infrastructure needs that must be met for telecommunication and social media to effectively support open, inclusive governance. These are access to and proper training in the use of these media and basic support platforms for IT in less-developed societies.

Despite efforts to expand access to the Internet and social networks in developed and developing societies alike, access to these platforms is still limited to the more affluent and, by implication, more technologically savvy elements of the public. In the domain of complex environmental issues, for instance, research suggests that broad electronic platform participation does not generally engage minorities and the poor to the same degree as it does other groups. Generally, more literate, politically energized, and activist groups and segments of the populace are more digitally connected. The latter are also more inclined to embrace the Internet enthusiastically and to extensively use it for organizing around policy issues (Dietz and Stern 2008). Access to technology by lower status groups is often limited – thus, a supportive education and training infrastructure to ensure optimal use is also needed. Experience in educational environments, for example, has shown that once IT is made available in schools where students and their families cannot otherwise afford it, suitable investments must also be made in training teachers – who can then train students – in order to make the best use of IT and social media (Tonn 2005).

Less appreciated is the need for a basic physical infrastructure platform to ensure social media and IT access and use, especially in developing countries. In East Asia, for instance, it has been found that one of the greatest infrastructure barriers to making telecommunication and social media effective governance tools for CT has been the lack of a simple but reliable electricity supply. In such contexts, the most readily effective means of ensuring both the adoption of networking technologies and their use is provision of such "low technology" solutions as, e.g., stationary bicycles hooked into handmade wireless computers – thus permitting the average IT user to "pedal his way to economic self-determinism" (Hurd 2005). Not coincidentally, such integrated power systems also require that participating groups are in close spatial proximity – another feature of polycentric governance – and that the platforms for these systems are simple but durable and ruggedly capable of reliable operations in monsoon or dry seasons.

Establishing and sustaining meaningful and effective public participation mechanisms may be the most formidable challenge facing polycentric governance for CKTS. While public participation and engagement of stakeholders are essential to CKTS governance, polycentric governance analyses are not always clear as to how – precisely – to facilitate such engagement.

The polycentric governance literature speaks to the need for multilevel governance able to deal with "different scales of market and government failures." It also refers to the ability to draw upon the experiences of cross-jurisdictional governance units in other areas of polycentric governance (e.g., economic development zones, tribal districts, school districts, water utility districts, charter cities, trade and monetary zones) – by arguing that specialized units for provision, production, financing, coordination, monitoring, sanctioning, and dispute resolution are needed to address issues of public trust and confidence (Araral and Hartley 2013).

Similarly, other polycentric governance scholars note the importance of encouraging active participation of local users – especially in managing private, locally managed, or even state-governed common-pool resources – through, among other

means, matching governance considerations to decidedly local needs (Ostrom 2010; Copeland and Taylor 2009; Grafton 2000). What has all this to do with CKTS? Is it transferrable? For CKTS, public participation requires several infrastructure needs – each of which has polycentric governance implications. These needs include support for both formal and informal science education about CKTS, empowering citizen input in research investments, funding R&D programs through bottom-up investigator- and public-initiated funding opportunities, and facilitating citizen participation in international – as well as US – debates and decisional processes (Roco 2012). Here, we consider three key infrastructure needs: (1) support for stakeholder dialogue, (2) sound design for public engagement processes, and (3) support for a wide range of participatory tools.

To facilitate public participation in polycentric governance arrangements, there is an emerging consensus that stakeholder dialogue requires, at some point, forums that permit face-to-face, structured discussions in which members of the public, government officials, and scientists involved in CKTS can clarify sources of technical and political disagreement and which can guide the decision-making process for which the form of technical solutions has been defined. This form of participatory infrastructure is sometimes called a *science court*, and it can be a vital tool for participatory governance, especially in light of the aforementioned progress made in advanced IT networking and virtual participatory opportunities (e.g., Futrell 2003).

Possible models for such a "science court" for CKTS are afforded by the efforts of the International Risk Governance Council (IRGC), which prescribes an independent participatory framework for identifying, assessing, and mitigating risk in general and of nanotechnology in particular. This prescribed framework consists of two frames – one for the next generation of products (passive nanostructures) and another for future generations (active nanostructures and nanosystems) whose products are more complex and which have broader societal implications; IRCG seeks to bring various stakeholders together to pursue coordinated governance methods (Renn and Roco 2006). Following summary consensus on various risks of CTs, appropriate regulations are then suggested for adoption by government agencies. Other models of public engagement for CTs have also been suggested, including congressional commissions that bring together scientists, consumer groups and other NGOs, and others without a *vested* interest in the outcome of funding decisions, citizen institutional review boards, or other decisional outcomes (e.g., National Citizens Technology Forum 2008).

Regardless of the particular form public engagement processes take, they must be carefully designed and crafted. Support must be provided for collaborative problem formulation and process design. In effect, provision should be made for allowing those who convene these forums – as well as those who participate in them – to jointly design them (Dietz and Stern 2008). Effective polycentric governance forms are based on ad hoc, decentralized, and often improvised means of collaboration, and such provision for localized, participant forum design exemplifies this.

Finally, a range of participatory approaches must be supported – ranging from those that elicit input in the form of opinions (e.g., surveys) to those that elicit

judgments and decisions from which actual policy may be derived (e.g., consensus conferences – see Mali 2008). Each of these types of activities, ranging from simple "consultative" bodies to more representative forums (to indirectly represent citizens) and finally deliberative entities such as the aforementioned "science courts," requires a specific support infrastructure to ensure effective governance (see Fig. 1). Among the major factors required are a change in the culture of participating government agencies from what has been characterized as closed, hierarchical decision-making cultures to one of openness and transparency, trained personnel who willingly embrace participation, and possibly changes in regulatory climates which mandate that agencies make, rather than negotiate, rulemaking and other decisions.

Getting to Polycentric Governance: Private-Public Partnership?

CKTS continues to grapple with the question of how to promote workable partnerships that promote innovation by crossing private and public sector boundaries. In turn, as we have noted, polycentric governance tries to avoid simplified division between notions of "public" versus "private" control. Flexible collaborative networks between for-profit enterprises and public sector entities are encouraged and should be guided by needs grounded in circumstance (McGinnis 2005).

There is a need for private-public partnerships that enhance investment opportunities, technological advancement, and public acceptance of CKTS. This has long been recognized as an important element of an overall CKTS governance strategy. Partnerships can help to effectively respond to regulatory uncertainty; promote a broad, democratic review of social impacts; and draw in broad, "evidence-based" assessments of economic, environmental, and other concerns – because they encompass economic development and growth concerns while at the same time embrace public interest concerns for societal oversight and risk management. Some observers contend that such partnerships work most effectively when they can identify funding mechanisms that allow private organizations to share the costs of their operations (e.g., National Citizens Technology Forum 2008).

One possible model for such partnerships is afforded by European regional-level technology assessments. These are designed to provide pragmatic, result-oriented forums for stakeholder interaction regarding the social implications of CTs (Evers and D'Silva 2009). In Belgium, for instance, the Flemish Technology Assessment project (funded between 2006 and 2010 by a private-public partnership formed by the *Flemish Institute for Advancement of Innovation through Science and Technology*) brought together nanoscientists and nanotechnologists in an interactive forum with lay groups to clarify underlying assumptions, visions, expectations, and concerns guiding nanotech research, development, manufacturing, and use. Experts were provided a variety of societal perspectives, needs, and concerns voiced by stakeholders in government, industry, and civil society. They were then required to respond to concerns through a series of "successive participatory rounds" in which experts reported on how they would integrate (or *had* integrated) societal

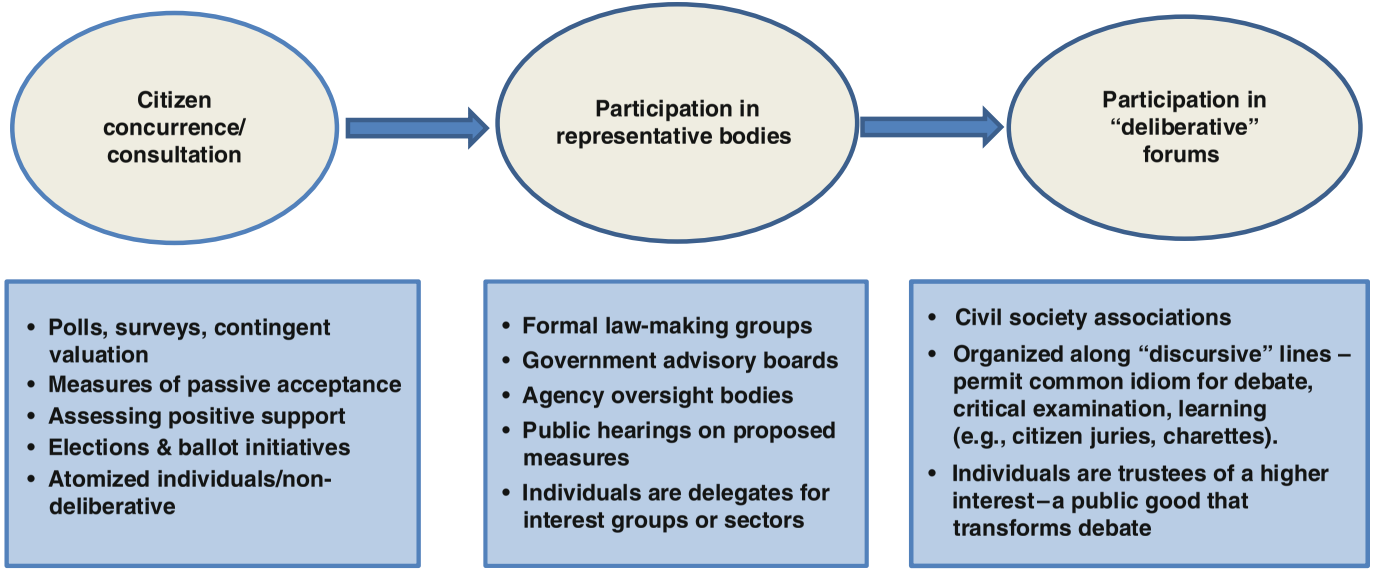

Fig. 1 Range of participatory approaches for polycentric governance

considerations into their research. The end product was a *normative round* of discussion where stakeholders and scientists evaluated the most plausible, short-term impacts of their research and how to manage them. This exercise allows for adjustment and alteration of nanotechnology implementation (Evers and D'Silva 2009).

Research Needs

Thus far, there have been precious few studies of polycentric governance for CKTS specifically. Most research on polycentric governance and its advantages for managing risk, embracing public participation, and enabling flexible, opportunistic management of policy domains has been in fields such as the environment, natural resources, and other global commons issues. An important research need, therefore, is the critical evaluation of polycentric governing institutions in the context of CKTS issues – through case studies, comparative analysis, or both. There are other challenges, among them the following. First, the rapid integration of nanotechnology, biotechnology, information science, and cognitive science in numerous settings since the beginning of the twenty-first century is outpacing the capacity of governance at any level to keep pace. Innovations develop more quickly than reform of governance processes and procedures.

Second, the growing emphasis in society at large in promoting innovation as a means of improving economic opportunities, environmental sustainability, and the overall quality of life is hastening sentiment for rapid introduction of technologies and their products. Third, and somewhat in contradiction of the first two concerns, the advent of ethical concerns over the impacts of CKTS upon the possible transformation of society in adverse ways (particularly synthetic biology and quantum IT systems and nanotechnology), and the challenges these ethical issues pose from the vantage point of uncertainty of regulation, voluntary constraint, or practice, may ironically be impeding CKTS development. In essence, in an uncertain governance environment, technology innovators might in some cases become hesitant to invest large sums of money on the introduction of new innovations only to see those efforts later thwarted by perceived regulatory intrusiveness resulting from public apprehensions.

Fourth, it has already become apparent that some societies have been able to adjust their governance of CKTS faster than others (e.g., smaller countries in Asia in particular) – creating a competitive asymmetry that in the long-term might be costly for other democratic societies grappling with finding effective polycentric governance approaches. Fifth, as we have seen in our discussion of "risk governance," a divergence of regulatory approaches has already begun to emerge – in both western Europe and North America in particular – from extending existing schemes of regulation which emphasize precisely characterizing risk on one hand, as opposed to a "softer" approach that operates with less than complete knowledge of risks on the other (Fleischer et al. 2012).

Table 1 Markets vs polycentricity

	Features	Remediation	CKTS examples
Markets	Easy entry and exit Transaction costs Many buyers and sellers	Institutions supporting free market structures and property rights Information availability	Private investment consortia Proprietary information sources with high "entry" fee – e.g., subscriber services
Polycentricity	Multiple actors of differing types Common-pool resources Disparate individual goals Issue-specific common goal	Institutions enabling equal access Delineation of the bounds of autonomy with regard to specific issues Multi-government solutions	Research parks Silicon Valley Deliberative engagement board and review bodies Risk governance boards for biotechnology

Adopted from Araral and Hartley 2013

In sum, it might be useful to compare polycentric governance as a possible approach to overcome these hazards, with the most likely alternative – reliance solely on market-based solutions. Table 1 (below) is an effort to compare markets and polycentricity along two dimensions – their features and how they rectify.

In effect, in science and technology, actors tend to pursue individual interests while a collective but implicit research agenda develops. The tacit authority structure resembles a market system that accommodates multiple opinions while rewarding activities that complement the collective agenda and research progress are an expression of aggregated individual interests.

Polycentric governance, by contrast, seeks to nurture a holistic approach with shared methodologies, theories, and goals, which is quite different from traditional forms of collaboration in which a division of labor separates disciplines from each other. It also renews the focus on people's capabilities and human outcomes, rather than allowing decisions to be technology-driven, and seeks to transcend existing human conflicts to achieve vastly improved conditions for work, learning, aging, and physical and cognitive wellness and to achieve shared human goals. This notion of governance requires that individuals be willing to expend considerable amounts of time and energy in seeking out a commonly acceptable solution and participating, in some fashion, in its implementation (Araral and Hartley 2013). In so doing, it seeks to chasten people against "free rider" action and in favor of collective well-being.

As Table 1 suggests, polycentric governance approaches compel us to carefully consider the extent to which we, as a society, are committed to CKTS as a common-pool resource, acknowledging the diversity of actors and their values, how disparate the goals of actors might be (e.g., profit as opposed to risk aversion and protection

of public interest), and the aspiration to maximize equal access to the benefits – as well as he burdens and risks – of CKTS.

Conclusion

Polycentric governance affords a number of advantages for meeting the needs of CKTS, including ad hoc institutional arrangements that permit bottom-up, multiple-actor governance; cooperative use of physical and virtual knowledge space; and facilitating collaboration within locally accessible institutional frameworks that are flexible enough to adapt to new opportunities and challenges. Among the latter are the need to match polycentric governance principles to CKTS problems through investing in consensus building or risk governance frameworks; developing repositories to collect, disseminate, and translate CKTS information on risks to lay audiences while simultaneously protecting proprietary and national security information; and utilizing telecommunication and social media to support open, inclusive governance. Overcoming these challenges will require public-private partnerships that encourage investments, further technical advances, and hasten public acceptance through facilitating stakeholder forums that bring scientists and nonscientists together in ways that help clarify societal, including ethical and legal, concerns over CKTS. Among the virtues – and vices – of democratic polities is a tendency to "go slow" in unleashing new technologies: harnessing them with regulations designed to abate risk, but which may have the unintended consequence of constraining innovation. The balance between these polar outcomes is difficult to manage. Further investigation of polycentric governance innovations in this regard would be a fruitful avenue of study.

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