Neoliberalism and the Production of Environmental Knowledge

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ABSTRACT: In order for nature/society scholars to understand the dynamics of environmental appropriation, commercialization, and privatization, we must attend to the production of the environmental science that enables them. Case studies from anthropology, geography, history of science, science and technology studies, and sociology demonstrate that the neoliberal forces whose *application* we study and contest are also changing the *production* of environmental knowledge claims both inside and outside the university. Neoliberalism's core epistemological claim about the market's superiority as information processor has made restructuring the university a surprisingly central project. Further, because knowledge has become a key site of capital accumulation, the transformative reach of neoliberal science regimes extends outside the university into the various forms of extramural science, such as citizen science, crowdsourcing, indigenous knowledge, and local knowledge. Neoliberal science regimes' impacts on these forms of extramural science are strikingly similar, and quite different from the most common consequences within academia.

KEYWORDS: neoliberal university, citizen science, crowdsourcing, indigenous knowledge, local knowledge, science regimes

Political ecologists and critical nature/society scholars have a long history of studying the application of environmental physical science to promote colonial and neocolonial agendas (e.g., Blaikie 1985; Davis 2007; Fairhead and Leach 1996; Leach and Mearns 1996; Neumann 1988; Turner 1999), legitimize state or corporate appropriation of local resources (Braun 2002; Hecht 1985; Hollander 2008; McCarthy 2002; Prudham 2005; Sayre 2002), and deny environmental and biophysical damage caused by corporations (Guthman and Dupuis 2006; Kirsch 2011), By contrast, we have paid comparatively little attention to the production of environmental knowledge claims (but see Demeritt 1998, 2001, 2006; Duvall 2011; Ellis and Waterton 2004; Forsyth 2003; Raffles 2002; Robertson 2006) even though we cannot understand the environmental management frameworks and policies applied at our field sites without analyzing the knowledge claims that enable them.

The production of those claims is a surprisingly central site of neoliberalization. While there is much research still to be done on the neoliberalization of universities, doing so is relatively straightforward, and there is already a substantial body of literature about it. Knowledge claims produced outside the academy, which have taken on increasing economic and academic significance since 1980, present a far less centralized unit of analysis (indigenous knowledge, citizen science, crowdsourcing, etc.). Yet neoliberal impacts on nonacademic knowledge production

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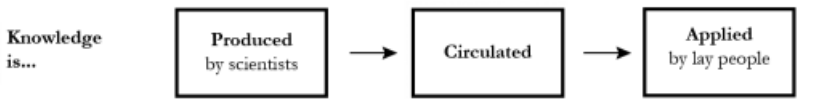
turn out to be strikingly similar across this disparate range of settings, and also notably different from the most common consequences of the neoliberalization of academia.

Science Regimes

In political ecology and critical nature/society studies more broadly, we attend carefully to the interested application of environmental science in the service of resource appropriation, commodification, and privatization. But the political-economic forces we study in the field have an equally powerful impact on the ways that environmental science is produced in the first place, shaping a) the questions investigated and, perhaps more important, funded; b) the beneficiaries of science; and c) the "principles of vision and division" with which natural scientists (and we, too) think (Bourdieu 1998). We are accustomed to acknowledging political-economic influences on the production of biomedical knowledge claims. We shake our heads over reports of conflicts of interest in clinical drug trials (Vioxx, anyone?), but somehow lose sight of the fact that quite similar dynamics are at work in environmental physical science as well.

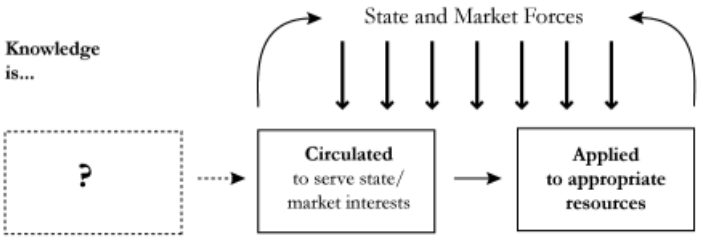
To more fully incorporate these dynamics into our research, we need an analytical model that links scientific production, circulation, and application to each other and to larger political economic forces. Conventional wisdom paints a simple, unidirectional picture of this process (Figure 1; Goldman and Turner 2011). In this model, knowledge is produced by scientists and then transferred to people who apply that knowledge in the way scientists envisioned. There are very few actors, no feedback among the stages, and no agency on the part of those who apply scientific knowledge. Nor is there any recognition of the broader political-economic context within which this process plays out.

Figure 1. Linear model of knowledge transmission



The typical political ecology version of this model is somewhat more nuanced in that the tension between individuals' agency and political economic forces is clearly visible (Figure 2). Production is typically black boxed as an unproblematic feeder into more important processes, though, and there is still no feedback among the stages of the model.

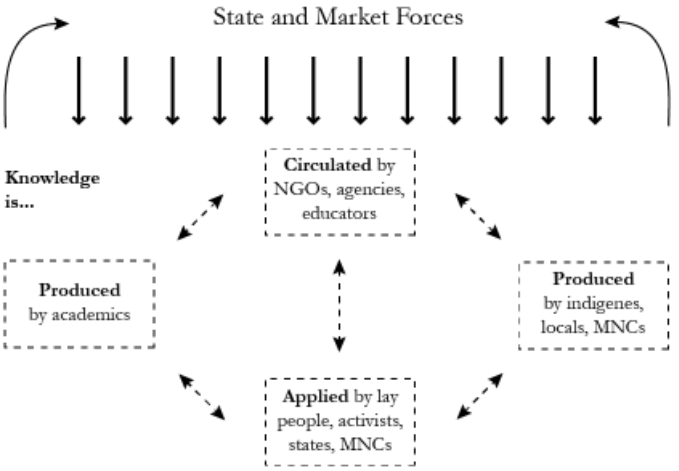
Figure 2. Typical political ecology model of knowledge transmission



Scholarship in science and technology studies (STS) paints a far more complicated picture, demonstrating the deep interconnections among knowledge production, circulation, and application (Figure 3). Historian of science Dominic Pestre (2003) coined the term *science regime* to describe this complexity, and the tensions between the agency of individuals and the larger

political-economic context in which they are embedded. Pestre's research demonstrates that the source and guiding philosophy of science funding and management at a particular place and time deeply shapes scientists' conditions of production, the content they produce, and how that content is circulated and applied. Scientists have never worked under circumstances of their own choosing, and those circumstances shape (but do not determine) their research practice and even their findings.

Figure 3. Model of science regimes



In any given historical moment and institutional context, relations among scientists, states, and economic elites create a distinctive science regime. In the United States, European Union, and other parts of the world—including Australia, China, New Zealand, and Japan—the current science regime is increasingly neoliberal.

Neoliberal Science Regimes and Their Impacts on Academic Knowledge Production

Universities are embroiled in a messy, uneven, and contested process of neoliberalization. They have lots of company: the past three decades have brought the neoliberalization of many formerly public projects, such as K-12 education, urban planning, health care, and environmental management. As demonstrated by Phillip Mirowski (2011), however, *science and its current institutional locus—the university—turn out to be surprisingly central to neoliberal agendas.* Beyond the arguments about market-based efficiency that can be applied to all of the sectors listed above, the keystone of neoliberal philosophy is an epistemological argument that the market is the superior information processor, knowing more than any individual ever can. Thus in neoliberal thought and increasingly in neoliberal science policy, university professors and researchers are viewed as at best embarrassingly misguided in their truth claims, and at worst actively harmful to the proper functioning of society. Universities have thus been subject to passionate attacks from neoliberal theorists for decades, as evidenced in the writing of Friedrich von Hayek and other members of the Mont Pelerín Society, such as Milton Friedman and George Stigler.

The policies and practices that stem from neoliberalism's very distinctive set of claims about epistemology and the university take forms that are nationally specific and operationalized differently by discipline and even by campus. As Canaan and Shumar describe it: "the context of

the political economy of globalization and the rise of neoliberal economic ideology … shape the stories of higher education being told in different countries and under different types of educational systems. … [These] local differences … are the result of different penetrations of media, migration, cultural, economic, finance and other flows" (2008: 1). Despite this variation, there are commonalities. I address five here, synthesized from case studies on a wide range of academic fields and national contexts: reduction in public funding for universities, separation of teaching and research, the replacement of peer review with market-based mechanisms, the tyranny of relevance, and the formidable strengthening of intellectual property protections.

The first common characteristic of neoliberal science regimes is redistribution of the costs of higher education from the public sector to the private (Mirowski 2011; Nedeva and Boden 2006). This trend is strikingly broad, with substantive drops in the percentage of federal funding for universities in almost all industrialized countries. A 2007 report by the Institute for Higher Education Policy found that between 1995 and 2003 the proportion of university funding provided by the public sector dropped in all but 4 of 51 countries surveyed and was replaced by private funding, nearly two-thirds of which came from household contributions (Hahn 2007: 4–6). Vincent-Lancrin (2006) describes a similar trend: public funding for universities (excluding grants for specific research projects) in the 16 countries of the Organization for Economic Cooperation and Development he surveyed declined from 78 percent to 65 percent between 1981 and 2003, with Australia, Denmark, Finland, Greece, Ireland, New Zealand, Spain, Turkey, and the UK all experiencing larger than average drops. Further, the distribution of public funds for universities within nation states was increasingly determined through research evaluation metrics (Vincent-Lancrin 2006: 179–182). Thus the actual decrease in public funding has been more severe for many universities than the national average would suggest, while a few elite research institutions have enjoyed funding increases.

In the United States, state-level funds for public universities have fluctuated substantially over the past decade. Large cuts in the early 2000s (Mirowski 2011; Rizzo 2004) were followed by modest increases in the middle of the decade (Slaughter and Rhoades 2004), now undone by the severe economic downturn that began in 2007. According to the Center on Budget and Policy Priorities, in 2011 43 out of 50 US states cut spending for higher education, in many cases quite substantially;[1] nationwide, per student public spending has dropped to a 25-year low (Martin and Lehren 2012).

Ideologically, this striking downward trend in public funding for universities has been driven by the reframing of education as an individual's investment in her own human capital rather than a public investment for the greater good of society (Kaye et al. 2006; Lambert et al. 2007; Mirowski 2011; Nedeva and Boden 2006; Slaughter and Rhoades 2004). As Slaughter and Rhoades explain, the shift in federal funding for higher education in the United States from direct funds to universities to loans to individual students (or their parents) has been justified by,

> the growing idea that higher education is largely a private good, with the benefits going primarily to individual students (who are increasing their human capital), so students and their families should be expected to bear a larger share of the costs. The externalities of higher education, the social benefits beyond the student, are overlooked and undervalued. Over time, the benefits of any expanded public investment in broader access to higher education have come into question. (2004: 283)

A second common characteristic of neoliberal science regimes is the increasing separation of research and teaching (Gibbons et al. 1994; Lambert et al. 2007; Mirowski 2011; Nowotny et al. 2001; Slaughter and Rhoades 2004), with the former increasingly privileged as a source of external revenue. In the US, the reduced emphasis on teaching has taken the form of differentia-

tion among academic staff. The percentage of untenured faculty—both itinerant and long-term adjunct positions—has skyrocketed. The American Association of University Professors' Contingent Faculty Index, a study of hiring practices at 2,617 US colleges and universities, found that between the 1970s and 2005 the percentage of tenure and tenure-track faculty dropped sharply from approximately 57 percent to just 35 percent (reported in Gravois 2006). In Europe the separation of research and teaching is occurring at the campus level. As mentioned above, performance-related metrics like the UK's Research Assessment Exercise redistribute funding among campuses, cutting funds and increasing course loads for the majority of universities (Nedeva and Boden 2006; Strathern 2000).

A third common characteristic of neoliberal science regimes is the circumvention of existing peer-review systems. Sergio Sismondo (2007, 2009) has demonstrated that approximately 40 percent of all articles in biomedical journals are planned and written by biomedical companies in a comprehensive privatization that he refers to as "ghost management." In the most egregious case so far uncovered, Elsevier produced multiple issues of six fake journals. These journals appeared to be peer reviewed, did not disclose their corporate funding (Grant 2009), and were distributed to tens of thousands of physicians in Australia between 2000 and 2003 (Singer 2009).

Beyond such illicit circumventions of peer-review gatekeeping, there are now explicitly privatized and commercialized peer-review systems, such as the Faculty of 1000 (F1000), an online site in which nominated faculty provide a brief description and rating of published articles. F1000 seems to share some weaknesses of the current peer-review system, such as cronyism and uncredited delegation: the *Chronicle of Higher Education* reported that many of the nominated members are assigning these unpaid reviews to their students rather than writing them themselves (Macilwain 2011). The larger issue, however, is that F1000 is now selling its privately produced reviews and research quality evaluations as an alternative to existing metrics through a partnership with EBSCO, one of the largest pay-per-view online academic content providers.[2]

A fourth common characteristic of neoliberal science regimes is the tyranny of relevance: the prioritization of knowledge produced to meet market needs at the expense of noncommercial research in the humanities, much of the social sciences, and even basic science (Canaan and Shumar 2008; Gibbons et al. 1994; Kleinman 2003; Lave et al. 2010b; Moore et al. 2011; Nedeva and Boden 2006). Canaan and Shumar argue that:

> the emphasis today is on applied research that can be turned into a marketable commodity. … [As a result,] *the humanities and the social sciences are becoming increasingly ghettoized* … [viewed by administrators as] a necessary sign of university education that should either be rationalized by making the teaching cheaper (such as online courses in the U.S. or by giving universities less income for arts and social sciences than for business, law and natural sciences in the U.K.) or should be instrumentalized by somehow bringing this research in line with the more profitable forms of research at the university. (2008: 10 and 16; emphasis added)

This trend was already clear in the early 1990s, as documented in *The New Production of Knowledge,* a germinal work on the transformation of science in Europe and the United States by Gibbons et al. (1994). They wrote that, "Less and less it [research] is curiosity-driven and funded out of general budgets which higher education is free to spend as it likes; more and more it is in the form of specific programmes funded by external agencies for defined purposes," as "the scientific industrial system [attempts] *to filter science through the sieve of industrial needs*" (Gibbons et al. 1994: 78, 163; emphasis added).

In addition to narrowing the topics of research, the neoliberal emphasis on market relevance leads many researchers to jump from topic to topic in search of funding rather than pursing a

sustained, self-directed research program (Gibbons et al. 1994: 86), creating a profound instrumentalization of academic research. According to Nedeva and Boden, under neoliberal science regimes,

> academics produce what they can sell and what is immediately and directly useable by "customers." … There is an observable epistemic shift whereby academic[s] research in areas which generate financial support, they generate knowledge that they can sell and tend to present it as immediately and directly useful by "customers." (2006: 278, 279–280)

The final common characteristic of neoliberal science regimes' impacts within universities stems from the stunning expansion of intellectual property protections, which has been central to neoliberal strategies of capital accumulation (Mirowski 2011; Nedeva and Boden 2006; Nowotny 2005; Nowotny et al. 2001; Tyfield 2010). As Pestre notes, the common way to characterize that expansion, "is to speak of a new movement of enclosure. The analogy is that we face a privatization of the 'commons of the mind' (what public science used to be) which recapitulates, several centuries later, the privatization of the 'common land' in early modern Britain" (2005: 34–35).

STS scholars have documented this new wave of enclosure in fascinating detail through the recent history of patent expansion in the United States (Biagioli 2006; Coriat and Orsi 2002; Geiger and Sa 2008; Mirowski 2011; Popp-Berman 2008). Briefly, beginning in 1980 with *Diamond vs. Chakrabarty* and the Bayh-Dole Act (and continuing on through further legal cases, acts of Congress, and executive orders by US presidents), US law has strikingly expanded what can be given intellectual property protection through patenting. It is now possible to patent anything from living beings to business practices, and to patent discoveries stemming from federally funded research whether by corporations, which receive the lion's share of federal research dollars, or by researchers at universities. The dramatically fortified US patent regime was then extended internationally in the form of the Trade Related Aspects of Intellectual Property Rights Agreements through a small coterie of US corporations' successful hijacking of the Uruguay Round of the General Agreement on Tariffs and Trade in 1994 (see Tyfield 2010 for a very useful history).[3]

The treatment of *knowledge as a target of appropriation,* an undercapitalized realm that can restart the process of capital accumulation, is a signature of neoliberal science regimes (Tyfield 2010). As Canaan and Shumar write, "In the new economy, knowledge is a critical raw material to be mined and extracted from any unprotected site; patented, copyrighted, trademarked or held as a trade secret; then sold in the marketplace for a profit" (2008: 4). Academia, however, is only one source of this raw material. Knowledge produced outside the university has also been central to neoliberal strategies of accumulation, and thus to neoliberal science regimes. Before moving on to extramural science, it is worth noting that the environmental sciences—particularly newly prominent ones like the study of climate change, biodiversity loss, or environmental mutagens—seem to be especially vulnerable to these last two trends. Research in these fields has been catalyzed by a sense of crisis rather than by scientific breakthroughs, resulting in relatively underdeveloped content often cobbled together from pieces of preexisting fields. In addition, these fields emphasize the complexity and particularity of the systems they study, leading to high levels of uncertainty. These new environmental sciences focus on issues in which the general population and markets (in cases such as carbon trading and weather derivatives) have powerful interests, which can lead them to intervene in scientific debates. Finally, unlike say particle physics, many environmental sciences focus on subjects about which lay people have substantial knowledge. All of this makes the environmental sciences more open both to the neoliberal emphasis on privatized and commercialized knowledge, and to extramural knowledge providers (Lave 2012b).

Neoliberal Science Regimes' Impacts Outside the Academy

Universities are the most widely recognized sources of knowledge production, but they are hardly the only source as phenomena such as the resurgence of bioprospecting demonstrate. Following the lead of neoliberal science and accumulation regimes beyond the ivory tower to new sources of intellectual raw material turns out to be far harder than it initially appears. Unlike the university, which presents a broad but relatively well-defined target, extramural knowledge production[4] is geographically diffuse and confusingly demarcated. Instead of the fairly integrated body of existing literature on the university reviewed above, scholarly research on extramural knowledge production is fragmented into separate literatures on amateur science, indigenous knowledge, local knowledge, crowdsourcing, commercial science, and citizen science. These literatures rarely refer to each other despite the fact that most of them are studied in a common set of fields (anthropology, geography, history of science, sociology, and STS); puzzlingly, they do not even seem to view each other as engaged with similar issues. Further, most of the literatures on extramural science do not address neoliberalism despite the fact that the resurgence of academic and policy interest in extramural science has very clear neoliberal roots. In this section I pull together the disconnected literatures on extramural knowledge production, highlighting their commonalities and demonstrating that neoliberal science regimes are having notably similar impacts on them.

History and Forms of Extramural Knowledge Production

As late as the mid-1800s, there was far less separation between full-time scientists and those we would today regard as amateurs. Certainly, there were very real class differences[5] between those who could afford to devote their energy to science and those for whom it could only be a part-time pursuit, but they saw themselves as engaged in a common enterprise. Part- and full-time scientists pored over the same texts, shared their knowledge and collections through local societies, and conveyed their findings in periodicals that did not screen authors by professional status (D. Allen 1976; Keeney 1992; Knell 2000; Kohler 2006; Oleson and Brown 1976; Secord 1994). Full-time scientists needed a network of collectors to bring them specimens, and some amateurs relied on professionals for financial support and in-depth information (Keeney 1992; Reingold 1976).

In the mid- to late-1800s, full-time scientists began a process of *professionalization* that excluded their former colleagues. This process featured certification through formal university degrees in science, and the foundation of both professional societies to which only full-time scientists could belong, and of journals for which only professionals could write. The shift from field science to lab science was also significant, as the expensive apparatus required for lab science shut amateurs out of mainstream scientific practice (Keeney 1992; Reingold 1976). The relocation of scientific practice from venues open across class, such as the pubs that were the center of amateur botany in England, to venues open only to the upper classes was another powerful technique of exclusion (Secord 1994).

Professionalization was accompanied by *appropriation*. The collectively developed body of knowledge was recast as the product and property of white, Western, professional scientists who both published without credit to the broader community that enabled their conclusions, and limited public access to still growing collections (Secord 1994). By the late 1800s, only professionals had legitimate access to the domain of science (Reingold 1976).

Extramural science did not dissolve in the face of these twin processes of professionalization and appropriation, but it certainly dropped from academic view. Neither natural nor social

scientists paid much attention to knowledge generated outside the academy during most of the twentieth century. Around 1980, however, extramural science suddenly experienced a dramatic resurgence in visibility in corporate, national, and international policy. Pharmaceutical companies embarked on the current wave of bioprospecting/biopiracy in the 1980s (Brush and Stabinsky 1996; Hayden 2003; Shiva 2001), and the Environmental Justice movement began to gain traction in places like Woburn, Massachusetts (Brown and Mikkelsen 1990) and Cancer Alley in Louisiana (B. Allen 2003). Canada required integration of indigenous knowledge into environmental management policies in 1985 (Nadasdy 1999), and the Convention on Biological Diversity was signed at the Earth Summit in 1992, linking biodiversity preservation with indigenous knowledge. What these and many other state and corporate policy shifts have in common is a focus on, and increased legitimization of, environmental knowledge claims produced outside the academy.

The concurrent explosion of interest in extramural science in academia is striking both for its exponential character (98.8 percent of articles on extramural science included in the Web of Knowledge have been published since 1980 [Lave 2011]) and for its fragmentation into almost entirely disconnected sets of literatures. Some scholars address two forms of extramural science together (Fischer 2000; Graddy 2011; Harding 2008; Fairhead and Leach 2003; Leach and Fairhead 2002; and much of the Critical Geographic Information Systems (GIS) literature on Web 2.0); however, no one analyzes the range of types relationally as deeply interconnected phenomena.

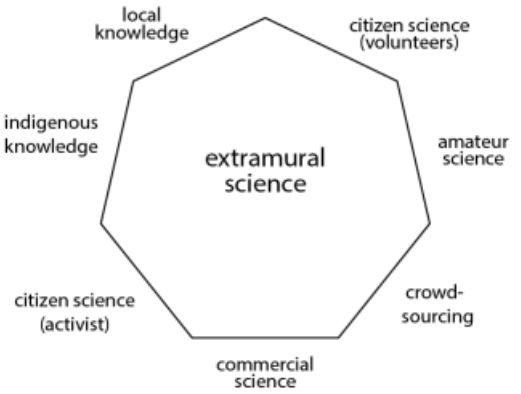
This is a startling oversight for several reasons. First, despite the varying locations, political economies, and histories of these different knowledge sources, there is a great deal of overlap among them. Most share a topical focus on the environment (particularly local knowledge, indigenous knowledge, and both forms of citizen science). They have similarly informal, low-budget conditions of production: no Big Science here. Perhaps most important, these different forms of extramural science are united by their shared relegation to Western science's foil in any number of highly loaded binaries including: universal/particular, dynamic/static, disinterested/embedded, oral/written, cerebral/embodied, and analytical/intuitive.

A second set of reasons it is unhelpful to study these disparate forms of extramural knowledge production separately is the commonalities in how they have been treated by others. As I argue in more detail below, extramural knowledge producers, regardless of type, are a current focus of primitive accumulation. They have also been the focus of a dramatic resurgence of interest by policymakers and by academics. Natural scientists faced with increasing competition for grants as a result of reductions in public funding were in need of extensive, inexpensive assistance collecting data. For their part, critical social scientists were inspired to seek alternative sources of knowledge by postcolonial agendas, and by the search for counterclaims to block the neoliberal intensification of state and corporate appropriation of local natural resources in both developed and developing countries.

Extramural knowledge producers share a predominantly environmental focus, lack of institutional base, and illegitimacy compared to university-produced knowledge claims. They also have a shared status as a target of appropriation, and of academic study catalyzed by a variety of neoliberal forces. Thus despite their obvious differences, the commonalities among types of extramural science make it imperative to consider them together (Figure 4).

Historians of science and STS scholars, particularly those concerned with the tension between elitism and democracy (Reingold 1976), use the term *amateur scientist* to describe people who play a recognized role in scientific communities but are not full-time scientists. Amateur scientists are the most visible continuity from the integrated scientific community of the early 1800s, and are clustered in fields where requirements for entry are not so costly, such as astronomy

Figure 4. Facets of extramural knowledge production



and archaeology. While the majority of amateur scientists hold relatively little legitimacy some, typically well-educated white-collar workers in developed countries, hold nearly professional status (Bhanoo 2011).

Anthropologists, geographers, and STS scholars use the term *indigenous knowledge* (also indigenous ecological knowledge, indigenous technical knowledge, or traditional ecological knowledge) to describe the agro-ecological knowledge of subsistence communities in geographically and politically marginal communities in the developing world (Dove 1996, 2006, and 2011; Harding 2008, 2011; Hayden 2003; Nadasdy 1999; Verran and Turnbull 1995). Indigenous knowledge producers are neither white nor white-collar, and are typically dismissed outside of the critical social sciences as holders of culturally embedded knowledge rather than active builders and curators of changing bodies of knowledge. Researchers of indigenous knowledge thus often take protective stances, analyzing these knowledge claims as targets of appropriation and agnotology (Brush and Stabinsky 1996; Greene 2004; Hobart 1993; Shiva 2001; Van der Ploeg 1993), critical sources of counterclaims (Bryan 2011; Davis 2007; Fairhead and Leach 1996; Rundstrom 1995), and beacons for sustainable practices (Mearns and Norton 2010; Nelson 2008; Reed 2009; Shaw et al. 2009).

STS scholars, sociologists, and environmental managers use the term *local knowledge* to describe similar agro-ecological knowledge when developed and held by geographically, economically, and politically marginal white people in developed countries (Fischer 2000; Irwin et al. 1996; Wynne 1996),[6] such as sheep farmers in Britain or heritage seed savers in Appalachia. As with indigenous knowledge systems, local knowledge systems are typically analyzed in the scholarly literature as marginalized, disregarded, or endangered (Fischer 2000; Irwin and Wynne 1996) or as critical resources for sustainable living (Graddy 2011; Irwin 1995).[7]

Crowdsourcing describes the emerging practice of distributed communal problem solving. Like amateur scientists, crowdsourcers are typically highly educated individuals without academic or corporate research jobs—"the kind of scientific talent and expertise that corporate America … [was not previously able] to tap" (Howe 2006). Corporations use crowdsourcing to address problems in-house R&D divisions have been unable to solve, most famously improving Netflix's recommendation algorithm (Thompson 2008). Though crowdsourcing has been addressed primarily in business, computing, and management journals (e.g., Elkins and Williams 2010; Leimeister et al. 2009; Terwiesch and Xu 2010), it is drawing increasing amounts of attention from critical GIS scholars intrigued by the democratizing potential of Web 2.0 cartography (Crampton 2009; Elwood 2008b; Goodchild 2007; Sui 2008; Wilson et al. 2009; Zook et al. 2010).

C*itizen science* has two quite different meanings. For natural scientists, citizen science describes the practice of enlisting large numbers of unpaid volunteers (typically white and well-educated) to collect data, most often for large-scale ecological or astronomical studies (Cohn 2008; Dickinson et al. 2010; Ellis and Waterton 2004; Greenwood 2005). By contrast, STS scholars use citizen science to denote practices of activist or counterscience centered in low-income communities, often of color, such as popular epidemiology, participatory mapping, and the knowledge production practices of the environmental justice movement more broadly (B. Allen 2003; Brown and Mikkelsen 1990; Corburn 2005; Craig et al. 2002; Elwood 2008a; Ottinger 2010).

Last, and closest to academic science, STS scholars, historians of science, anthropologists, and geographers study something that could be called *commercial science:* private sector knowledge claims developed in settings as disparate as Bell Labs, scrappy biotech start-ups, contract-research organizations, and even individual consultancies (Fisher 2009; Lave 2012a, 2012b; Mirowski and Van Horn 2005; Randalls 2010; Shapin 2008; Sunder-Rajan 2006). In the vast majority of these settings, knowledge claims are developed in formal settings by researchers with advanced academic degrees and high levels of scientific legitimacy. Like academic scientists, commercial scientists receive federal research funding, publish in academic journals, and present their findings at academic conferences (though with more severe intellectual property and secrecy constraints). These diverse forms of extramural knowledge have different geopolitical-economic positions, but a great deal of overlap in terms of the status of participants and the types of knowledge claims they typically produce. As I will argue in the next section, they have also experienced remarkably similar impacts from neoliberal science regimes.

Impacts of Neoliberal Science Regimes Outside Universities

Unsurprisingly, many scholars of commercial science are forcibly confronted with neoliberal emphases on the commercialization and privatization of knowledge production (Fisher 2009; Johnson 2009; Mirowski and Van Horn 2005; Randalls 2010). Similarly, many scholars of indigenous knowledge, where neoliberal strategies of primitive accumulation via biopiracy have had some impact, are also quite cognizant of neoliberal influences on their field sites (Bryan 2011; Greene 2004; Hayden 2003). By contrast, in the literatures on amateur science, local knowledge, crowdsourcing, and both types of citizen science there is as yet little discussion of neoliberalism, which seems to be viewed as irrelevant to the micropolitics and struggles for legitimacy of knowledge developed outside the academy. But while neoliberal science regimes' influences on knowledge produced outside the university are different from those inside the academy, they are just as striking.

A central impact is a new wave of appropriation of labor and knowledge. Both amateur and citizen scientists provide vast amounts of unpaid work for physical scientists. Citizen science projects, in particular, are increasingly common; the Cornell Laboratory of Ornithology (CLO), the citizen science mothership in the United States, lists more than 600 volunteer-staffed projects (Dickinson et al. 2010: 150). As CLO researchers wrote in a recent review article, "The bang for the buck can be good" (ibid.: 151). Their Project FeederWatch, for example, is supported by volunteers who not only pay fees to participate, but also contribute an estimated $3 million per year in unpaid labor. Environmental scientists are even reaching back into historical records to posthumously convert amateur naturalists into citizen scientists, most visibly in the case of Thoreau (Primack et al. 2009). And while crowdsourcers may be paid, they are employed only on an as-needed basis and have no job security or benefits. The winners of big prizes such as the Netflix challenge get the most press, but it is important to note that the vast majority of crowdsourcing contracts are far less remunerative (Howe 2006).

In addition to labor, there is also a new wave of appropriation of both indigenous and local knowledge, typically carried out by ethnobotanists and other bioprospectors in the service of pharmaceutical and agricultural biotechnology companies. Arturo Escobar described this process of appropriation in a classic 1996 article:

> This second form of capital relies not only on the symbolic conquest of nature (in terms of "biodiversity reserves") and local communities (as "stewards" of nature); it also requires the semiotic conquest of local knowledges, to the extent that "saving nature" demands the valuation of local knowledges of sustaining nature. … This triple cultural reconversion of nature, people, and knowledge represents a novel internalization of production conditions. Nature and local people themselves are seen as the source and creators of value. (Escobar 1996: 57)

In striking contrast to these destructive dynamics of appropriation, neoliberal science regimes' privileging of privatized and commercializable knowledge has also generated a big boost in the credibility of extramural science and the people who produce it, with contradictory effects. On the one hand, commercial knowledge claims are no longer seen as potentially compromised by conflicts of interest, but instead as legitimized by market forces. On the other hand, environmental consultants have been able to establish serious scientific credibility in startling upsets of the traditional construction of scientific legitimacy (Briske et al. 2011; Lave 2012a, 2012b). Citizen scientists (of the activist persuasion) are now accorded a place at the table in many regulatory decisions (Brown and Mikkelsen 1990; Cohen and Ottinger 2011; Frickel et al. 2010; Moore et al. 2011; Ottinger 2009), and indigenous groups are consulted in developing environmental management plans (Fairhead and Leach 2003; Nadasdy 1999) in ways that were unimaginable in the 1950s, or even in the 1970s.

That neoliberal science regimes' impacts—positive and negative—are so unified across these seemingly disparate forms of extramural knowledge production, and yet so little remarked on in the scholarly literature strongly suggests that the academic boundaries among research on types of nonacademic knowledge production are not just artificial, but actively unhelpful. When looked at comparatively, trends invisible to researchers of particular extramural knowledge forms become strikingly clear.

Larger Implications

I have argued that political-economic forces shape not just the application of environmental knowledge claims, but also their production (see Figure 3), as conditions of practice both inside and outside the academy are increasingly influenced by neoliberal science regimes and knowledge producers' responses to them. Outside the academy, neoliberal science regimes have so far had interestingly contradictory affects: appropriation, privatization, and commercialization, on the one hand; increased visibility and respect, on the other. Do more credibility and a place at the grown-ups' table translate directly into autonomy, legitimacy, and vastly improved conditions for marginalized communities in the developing and developed worlds? Clearly not. But the hugely increased level of attention from policymakers, academics, and corporations is a notable shift from centuries of disregard and disempowerment, and may enable extramural knowledge producers sufficient legitimacy to participate in the production of credible scientific claims.

Inside the academy, however, the reported impacts of neoliberal science regimes have thus far been quite grim. Graduates are marooned with heavy debt loads at the same time that the devaluation of teaching seems to be reducing the quality of the education they receive. Peer review has long been flawed by cronyism, laziness, and elitism, but is delegating intellectual

gatekeeping to corporate interests really preferable? The evisceration of funding for the humanities, much of the social sciences, and basic science research is deeply distressing, and it is increasingly clear that the dramatic expansion of intellectual property protections is reducing research productivity rather than increasing it (e.g., Henry et al. 2003; Mirowski 2011: 140, fn1; Pestre 2005: 35; Rodriguez et al. 2007).

Impacts from neoliberal science regimes thus matter deeply to knowledge producers inside and outside universities worldwide as they radically and abruptly reshape our conditions of practice. It is important to note that the impacts do not stop there: the transformation of the organization, practice, and content of science has larger social justice impacts because of how such knowledge is circulated (or not) and how it is applied.

One issue arises from limitations on access to privatized knowledge and to research tools sequestered behind intellectual property firewalls. For example, Leigh Johnson has described how climate researchers at an American university created a spin-off business that developed hurricane forecasts for a major energy company. These privately held forecasts can predict hurricane paths seven days in advance within a range of 100 miles, while the publicly available forecasts developed by the US National Hurricane Center achieve the same track accuracy only 48 hours in advance (Johnson 2009). Imagine what might have been accomplished with public access to accurate forecasts of the paths of Hurricanes Katrina and Rita seven days in advance; at present, only a major energy company has access to such knowledge. Jill Fisher (2009) has demonstrated that clinical trials in the United States are largely filled with low-income patients who not only will never be able to afford the patented medication if the trial is successful, but who also would not otherwise have access to health care of any kind. The same players that shut low-income Americans out of access to health care—the insurance and pharmaceutical industries—generate profit by using their bodies to produce scientific claims. Kaushik Sunder-Rajan (2006) describes similar impacts from the privatized production of clinical trial data in India, with the added kick that the construction of medical centers and clinical trial facilities expropriates the land of people whose best employment prospect then becomes "volunteering" to be paid clinical trial participants.

A second issue arises from the ways in which privatized and/or commercialized knowledge can enable the neoliberalization of other realms. For example, the basic principle of neoliberal environmental management is to establish markets that offset environmental harms by internalizing their cost. But getting such markets up and running requires converting complex ecosystems services into tradable commodities. Without metrics that pare away the ecological specificity of particular ecosystems in order to abstract them into easily measurable, comparable units, market-based environmental management cannot function (Lave et al. 2010a; Robertson 2006). Creating these market-enabling metrics is thus a critical task of "science in the service of capital" (Robertson 2006).

In stream mitigation banking (SMB), an increasingly common form of market-based environmental management, for-profit bankers speculatively restore damaged streams to create a bank of "credits" that developers can buy in order to obtain a permit that allows them to destroy an inconveniently located stream elsewhere. SMB was established and spread very rapidly because there was a commodity-defining metric ready to hand: a privately produced stream classification system that was itself a product of neoliberal promotion of the privatization and commercialization of science (Lave 2012a, 2012b; Lave et al. 2010a). By market standards, this metric proved quite practical, enabling the stream mitigation market to function smoothly. By ecological standards, however, SMB has thus far failed because streams restored to create mitigation credits show no substantial improvement in ecological function or water quality (Bernhardt and Palmer 2011; Doyle and Shields 2012). The privately produced, market-ready

knowledge claims created as science was filtered through the sieve of commercial purposes—to paraphrase Gibbons et al. (2004: 163)—have enabled the spread of market-based environmental management and a new driver of environmental damage to streams. The broader Payment for Ecosystem Services paradigm of which mitigation banking is a part seems similarly vulnerable to the synergistic intersection of neoliberal science and environmental management regimes.

Obviously, the intersection of environmental damage and injustice is not new; the historians among us can provide all manner of heart-wrenching examples of environmental harms justified or hidden by past political-economic orders, from Bikini Island to Bhopal. What is novel is the market-based form these impacts take today, which raise particular kinds of challenges for critical nature/society scholars.

What then shall we do? These specific examples and the discussion that preceded them have clear intellectual implications for critical nature/society studies. In order to understand the dynamic application of neoliberal environmental policies and management practices, we must expand our research to include the interlinked production and circulation of the science that enables them. I would argue that we should also respond to neoliberal science regimes as activists: the neoliberalization of knowledge production has social justice implications that extend far beyond our livelihoods.

The first order of business is to decide what exactly we want to defend. As many have pointed out, before the advent of neoliberal science regimes the university was hardly Edenic (Apple 2005; Mirowski 2011; Slaughter and Rhoades 2004). Slaughter and Rhoades write that: "The not-too-distant past in higher education (like the continued present) featured fundamental social inequities, significant constraints on the free pursuit of knowledge, [and] a linking of the research enterprise to the purposes and mechanisms of the cold war" (2004: 33). Thus as Michael Apple wisely notes, we must be very careful about what parts of the old systems of higher education we choose to advocate (2005: 24).

Beyond this critical task of viewing the past without nostalgia, Dominique Pestre argues that we need to carefully evaluate neoliberal science regimes because we could actually be ambivalent about them if we chose to:

> First because operationality and pragmatism are not uninteresting criteria, far from it, criteria that we could just ignore or dismiss lightly; but also, and more profoundly, because the universal, epistemological and moral, values of science as "pure" knowledge and culture—notions and values that were invented in several steps from the late XVIIth to the late XIXth centuries to differentiate "us-in-the-West" from "them-in-the-Orient," and "us-the-scientists" from "them-the-laypeople"— are not indisputable and without drawbacks. Heavily loaded, "ideologically speaking," we cannot just accept them as non-problematic. (2005: 38)

Supporting this point, it is worth remembering that neoliberalization is not simply a result of top-down, structured processes, but also of individuals finding worth in and embracing particular components of neoliberal philosophies (Larner 2003). Some extramural knowledge producers have used the drive to commercialize their knowledge claims as a source of political leverage (as demonstrated by Tania Li's [2000] powerful analysis of indigenous groups choosing the "tribal slot"), and as Slaughter and Rhoades (2004) and Nowotny (2005) note, many academic administrators and researchers (including some with progressive agendas) have embraced greater connection to markets and fought for policy changes to enable them. If we took these arguments for ambivalence toward neoliberal science regimes seriously, our political agenda would include not just targeted rejection of particular aspects of neoliberal science management, but also re-appropriation of some of its core practices, such as choice, accountability, and "relevance," to more progressive ends.

Neoliberal science regimes have direct social and environmental impacts. As knowledge claims produced under neoliberalized conditions are circulated and applied they advance commercial interests, heighten the impacts of social inequality, and enable the neoliberalization of as yet un(der)capitalized realms. The same forces we see at work in our field sites shape the science underlying the policies we critique, as well as the counter-science we sometimes use to oppose them. We can no longer afford to ignore their interconnections in either our intellectual or political practice.

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NOTES

1. http://www.cbpp.org/cms/index.cfm?fa=view&id=1214 (accessed 14 November 2011).
2. http://www.prweb.com/releases/DynaMed/F1000/prweb8948133.htm (accessed 13 December 2011).
3. As Mirowski has noted (2011), patents are only one component of this broad expansion of intellectual property rights which also includes material transfer agreements (MTAs) and the extension of copyright and trade secrets provisions. MTAs, in particular, have become the intellectual property protection tool of choice as they are faster, easier, and cheaper to establish than patents.
4. I have borrowed the term *extramural science* from Ronald Barnett (2005). While I do not find it particularly evocative, I have yet to discover a better umbrella term for the wide range of knowledges developed outside the academy.
5. And in some cases racial and gender differences as well. The history of indigenous knowledge under colonialism often featured far sharper status distinctions than the predominantly Western history I describe here (e.g., Michael Adas' classic work *Machines as the Measure of Men*). Michael Dove (2011) has noted a more benign separation between indigenous and colonial knowledge producers, as mutual ignorance and imagination facilitated trade relations.

6. The strong constructivist positions of many STS scholars leads them to describe all science as local knowledge (Verran and Turnbull 1996; Wynne 1996: 382). Also, some scholars uncomfortable with privileging autochthony and the severe limitations that can accompany claims to indigeneity use *local knowledge* to describe knowledge production among groups typically considered indigenous (Evans 2011; Mutersbaugh 2006).
7. The age of the STS cites is telling: while local knowledge was prominent in the 1990s, it is not even included in the index of the current 2007 edition of the *Handbook of Science and Technology Studies.* The attention previously devoted to local knowledge seems to have gone into activist science and debates about the democratization of expertise.

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