

Retrospectives

Tragedy of the Commons after 50 Years

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This feature addresses the history of economic terms and ideas. The hope is to deepen the workaday dialogue of economists, while perhaps also casting new light on ongoing questions. If you have suggestions for future topics or authors, please contact Joseph Persky, Professor of Economics, University of Illinois, Chicago, at jpersky@uic.edu.

Introduction

Garrett Hardin's (1968) "The Tragedy of the Commons" has been incredibly influential in biology, ecology, and various social sciences, including economics. It has become a totemic reference to which tributes are regularly paid (for examples, see Feeny et al. 1990; Bajema 1991; Burger and Gochfeld 1998; Boyd et al. 2018). But "tragedy of the commons" has been transmuted into little more than a useful catchphrase, as if it were synonymous with free-rider problems endemic to public or collective goods. This obfuscates the usefulness of the concept of how a commons can function for the governance of shared resources. In this essay, we revisit Hardin's

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article 50 years after it was written to clarify, set the record straight, and explore its relevance in the twenty-first century.

We first remind readers that Hardin drew on both biological and economic theories of how competition worked and that he stressed the pressure that population growth would place on environmental resources. His narrative was very much in the public eye. After all, Paul Ehrlich's book *The Population Bomb* was a best seller in 1968. We describe Hardin's famous allegory of how sheepherders are likely to over-exploit a commons, which had a significant impact on how subsequent generations understood the phenomenon. Yet, perhaps surprisingly, few economists engaged with Hardin's paper in the decade following its publication. To our knowledge, no economists paid much attention to the biological or economic arguments behind Hardin's essay, nor to his argument that the tragedy of the commons required government-imposed limits on births. It took some time before the tragedy of the commons spread among economists, and then it was typically as a quick mention in the background of a discussion of providing public goods.

However, Elinor and Vincent Ostrom were more insightful. In particular, Elinor Ostrom dedicated much of her career to demonstrating how commons in the real world had not led and do not inevitably lead to tragic ruin, as Hardin had insisted. In 2009, she received the Nobel Prize in Economics because she "challenged the conventional wisdom by demonstrating how local property can be successfully managed by local commons without any regulation by central authorities or privatization."¹ In retrospect, and in the context of the work by Elinor and Vincent Ostrom, we can see that Hardin's famous sheepherder allegory failed to make two key conceptual distinctions: the allegory conflated the idea of a scarce resource with the governance of that resource, and it further conflated open access with commons, despite significant differences in those forms of governance. We will clarify these distinctions and thus explore the limitations of Hardin's view. Unfortunately, Hardin's distorted perspective on the commons often persists to this day in economic discussions. Thus, we discuss some applications and extensions of research on commons, including infrastructure, knowledge, and other issues. Interdisciplinary scholars have identified an expanding set of shared resources for which commons governance may effectively address social dilemmas.

Hardin's "Tragedy of the Commons"

Garrett Hardin (1915–2003) is well known in biology for his work on evolution and natural selection. He spent most of his career at the University of California, Santa Barbara, where he arrived in 1946 and stayed until his retirement in 1978. Hardin was also prominent as a public intellectual. He contributed to magazines, gave popular lectures, appeared on television and radio, and testified before many

¹For background material on Elinor Ostrom's Nobel Prize, see <https://www.nobelprize.org/prizes/economic-sciences/2009/ostrom/facts>.

congressional committees. In both his academic and nonacademic work, Hardin emphasized the need to control population growth. His “Tragedy of the Commons” essay is his most famous attempt to make his case, but it was neither the first nor the last attempt (as emphasized by Oakes 2016). A prominent early effort along these lines, “The Competitive Exclusion Principle,” appeared in *Science* magazine in 1960. In that article, Hardin (1960, 1292, emphasis in original) stated that “*complete competition cannot coexist*,” explaining:

- (i) [I]f two noninterbreeding populations “do the same thing”—that is, occupy precisely the same ecological niche in Elton’s sense—and (ii) if they are “sympatric”—that is, if they occupy the same geographic territory—and (iii) if population *A* multiplies even the least bit faster than population *B*, then ultimately *A* will completely displace *B*, which will become extinct.

Anticipating Michael Ghiselin’s (1974) bioeconomics and Edward O. Wilson’s (1975) sociobiology, Hardin combined, extrapolated, and generalized a result that he had found in biology and economics. In 1960, Hardin first anchored his competitive exclusion principle, also known as Gause’s principle. Specifically, Russian evolutionist Georgii Gause (1932) had shown in a series of experiments involving yeast and paramecia that when different species live in a shared environment and use similar resources, one species will tend to drive out the others. Hardin (1960, 1293) acknowledged the principle was hard to “prove or disprove” empirically, but further argued that “[t]he ‘truth’ of the principle is and can be established only by theory.”

Second, Hardin (1960, 1295) thought it was “possible” that principle “originated in economic thought.” Thus, as another source of inspiration for the claim that competition would destroy itself, he cited “the French mathematician” Joseph Bertrand. Commenting on Cournot’s duopoly model, Bertrand (as quoted in Hardin 1960, 1295–96) noted that if

one of the competitors will lower his price in order to attract the buyers to himself, and that the other, trying to regain them, will set his price still lower . . . there is no limit to the lowering of the price. Whatever common price might be initially adopted, if one of the competitors were to lower the price unilaterally he would thereby attract the totality of the business to himself.

Hardin (1960, 1296) thus stated baldly: “Any competitor knows that unrestrained competition will ultimately result in but one victor,” in part because unrestricted companies will form cartels or use intellectual property to block competitors. In international trade, Hardin argued, his proposed competition exclusion principles meant that the world would need to reconsider tariffs and trade barriers, to prevent one country from being the victor that drives all others from the market.

Of course, just as many biologists of the time were engaged in controversy over the actual reach of the competitive exclusion principle, many economists then and

now would take issue with the claim that all competition tends to monopoly. Even at the time, Gordon Tullock (1960, 95) stressed that Hardin's article "contains an error in economics. From the principle that complete competitors cannot coexist he deduces the development of monopolies." Tullock argued: "If the principle has any application to economics at all, it would indicate that one type of economic enterprise might, by multiplication of its members, replace another, but this would not lead to monopoly."

In Hardin's "Tragedy of the Commons" essay, instead of focusing on biological competitors with a fixed set of resources and similar needs, he added another dimension: the stress that population growth inevitably placed on environmental resources—"the world available to the terrestrial population is finite" (Hardin 1968, 1243). That was also the case with other natural resources, such as oceans, which people tend to think as "inexhaustible" (1245); national parks, about which he remarked "there is only one Yosemite Valley" (1245); air and rivers; and even "airwaves of radio and television" (1249). Scarcity was the origin of the economic, ecological, and social problem.

In what is probably the most-quoted portion of the essay (at least in classes in economics!), Hardin (1968, 1244) proposed a shepherd allegory to understand the basic motivation at work:

Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. . . .

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility *to me* of adding one more animal to my herd?" This utility has one negative and one positive component.

1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

In Hardin's (1968, 1245) view, individuals acted vis-à-vis the world and its resources as if they were "independent, rational, free-enterprisers," as if their action

had no impact on them, as if Adam Smith's invisible hand had actually worked and "decisions reached individually will, in fact, be the best decisions for an entire society" (1244). Rationally, such behavior was perfectly understandable: "Each man," explained Hardin, "is locked into a system that compels him to increase his herd without limit" (1244) or "a system of 'fouling our own nest'" (1245). The consequence was unavoidable. Because of the ongoing increase in population and humanity's shared use of the global commons, "the per capita share of the world's goods must steadily decrease" (1243), which would generate "misery" (1243) and "ruin" (1244).

At its core, Hardin's (1968) tragedy, captured in his shepherd analogy, illustrates a rather standard economics problem of interdependence, which involves issues of collective goods or external effects. After early analyses by Pigou (1920) and Knight (1924), these problems had received more attention and had been more frequently discussed in the mid- to late 1950s with the works of Samuelson (1954), Bator (1958), and Coase (1960) (for an overview, see Marciano and Medema 2015). Hardin offered quick and casual references to Adam Smith and Thomas Malthus, but he did not refer to any of the modern economists who had contributed to the study of how to deal with situations involving interdependence. Hardin also neglected prior work in economics that dealt with commons (for example, Gordon 1954 on fisheries).

Indeed, Hardin's (1968) shepherd allegory strikingly echoed the view Samuelson advanced in 1954: namely, that the economic problem of inefficient resource allocation does not come from the interdependence of resources but rather from the tendency of self-interested individuals to engage in free riding—the "hope to snatch some selfish benefit," in Samuelson's (1954, 389) words. For Hardin, the problem resided more in the *freedom* to use a resource rather than in the characteristics of the resource itself; significantly, he titled one of the sections of his article "Tragedy of Freedom in a Commons" (Hardin 1968, 1244).

To avoid the tragedy, Hardin argued for governance to constrain consumption and ensure sustainability. His advice was simple: stop making resources open to all. He pointed out that this step had already been taken with "food gathering, enclosing farm land and restricting pastures and hunting and fishing areas" (Hardin 1968, 1248). It should also be done, in Hardin's view, with "commons as a place for waste disposal" and with "pollution by automobiles, factories, insecticide sprayers, fertilizing operations, and atomic energy installations," as well as with "the commons in matters of pleasure," restricting, for instance, "the propagation of sound waves . . . in the public medium"—what he called "mindless music." All this would imply coercion, "the infringements on somebody's personal liberty." But in Hardin's view, it was the illusion and appearance of freedom associated with the philosophy of open access to resources that was actually coercive: "Individuals locked into the logic of the commons are free only to bring on universal ruin."

Hardin's (1968) primary focus and attack in his "Tragedy of the Commons" essay was on rising human populations: indeed, the subtitle of the article is "The Population Problem Has No Technical Solution; It Requires a Fundamental Extension in Morality." Hardin (1968, 1246) argued that the "freedom to breed" is

“intolerable.” He rejected appeals to conscience: “[A]n appeal to independently acting consciences selects for the disappearance of all conscience in the long run, and an increase in anxiety in the short” (1248). He insisted upon mutual coercion as the approach: “Coercion is a dirty word to most liberals now, but it need not forever be so” (1247). He referred to the United Nations’ Universal Declaration of Human Rights, which held that all choices about the size of families should be made by families. Hardin responded: “It is painful to have to deny categorically the validity of this right; denying it, one feels as uncomfortable as a resident of Salem, Massachusetts, who denied the reality of witches in the 17th century” (1246).²

Hardin (1968) recognized two solutions to the tragedy of the commons: government regulation and privatization. Both solutions rely on collective action through government to introduce constraints on resource consumption. The approaches differ substantially in terms of the manner in which ongoing (month-to-month, day-to-day, minute-to-minute) resource allocation decisions are made. Government can constrain consumption by directly managing or regulating resource use. Alternatively, government can establish a system of private property rights delineating ownership of the resources. The former presumes government will consider the aggregate effects and manage resource use efficiently over time, and the latter presumes well-defined private property rights will facilitate market exchanges and thereby lead to an efficient allocation of access and use rights and, consequently, efficient resource management over time. In the case of population growth, Hardin’s essay does not explicitly contemplate a privatization approach (like a transferable right for any adult to be the biological parent to one child). Government regulation of population is necessary, Hardin (1968, 1248) claimed: “Freedom to breed will bring ruin to all.”

Early Interpretation and Incorporation within Economics

Hardin’s (1968) article attracted a reasonable degree of public attention, but most economists did not much refer to Hardin. The few who did argued that Hardin was cited for having coined an interesting expression for what economists already knew. For example, in one of the first references made by an economist to Hardin, Dales (1975, 495) explained that because of the difficulties in assigning property rights, “the expected outcome followed—overuse, congestion, premature depletion, or extinction, depending on the particular characteristics of the case—and

²As Bajema (1991) notes, Hardin was often willing to “break social taboos.” Along with calling for government-mandated population control, he signed with 51 others a *Wall Street Journal* op-ed called “Mainstream Science on Intelligence,” written by Linda Gottfredson ([1994] 1997), that discussed average racial-ethnic differences in intelligence measured in terms of IQ. Another striking example is his 1974 essay, “Living in a Lifeboat,” in which he again insisted on the need to control population growth and asserted that the problem of “Christian-Marxist” idealism is that “the sharing ethics . . . leads to the tragedy of the commons” (Hardin 1974, 562).

the value of the resource dropped toward zero. ‘The tragedy of the commons,’ to use Hardin’s apt phrase, unfolded inexorably.” Along the same lines, a few years later, one read that “[w]ithout private property, society will experience the ‘tragedy of the commons’—ownership by all actually means ownership by none” (Carroll, Ciscil, and Chisholm 1979, 607). At the beginning of the 1980s, a few economists discussed again the problem of fisheries, with a similar tone. For instance, Johnson and Libecap (1982) referred to a series of articles on fisheries as common-property resources, and they mentioned Hardin’s 1968 article only in passing, as if it were a necessary reference.³

But over time, the “Tragedy of the Commons” article became one among many that formed “the large literature” devoted to “common-property management” (Thiesenhusen 1991, 18). In the economics literature, it was no longer distinguished from the articles written by economists themselves, and Hardin was put on the same footing as the economists who had worked on property rights. He was thus cited as a scholar defending a neoclassical “perspective” (Carroll, Ciscil, and Chisholm 1979) or “paradigm” (Swaney 1981) and lumped together with Coase (1960) and Demsetz (1967), despite their very different perspectives and approaches. The context of Hardin’s (1968) work, with its focus on overpopulation and advocacy of mandatory government control over population growth, largely faded away.

The Ostroms

Elinor and Vincent Ostrom noted as early as 1971 that “Garrett Hardin had indicated that these strategies [such as free riding] give rise to ‘the tragedy of the commons’ where increased individual effort leaves everyone worse off” (V. Ostrom and E. Ostrom 1971, 207). In 1973, Vincent Ostrom referred to Hardin and described the tragedy as follows (V. Ostrom 1973, 210–11):

Individualistic decision making applied to common-property resources will inexorably result in tragedy unless the structure of decision-making arrangements can be modified to enable persons to act jointly in relation to those resources as a common property. Potential recourse to coercive measures will also be necessary to preclude a hold-out strategy and regulate patterns of use among all users. Unrestricted individualistic decision-making in relation to common-property resources or public goods will lead to the competitive dynamic of a negative-sum game: the greater the individual effort, the worse off people become.

³One set of writers even supposed that Hardin had “documented more fully” the problem of overexploitation (Balachandran, Fisher, and Stanley 1989, 261), which is obviously an exaggeration: Hardin had given no more than a few examples. Furthermore, despite Hardin’s depiction, commons existed and were successfully managed in various ways in medieval England and many other parts of the world for a very long time (Dahlman 1980; Buck Cox 1985; Bannon 2017).

These references were not different from those of most economists at that time. But the Ostroms, and especially Elinor, disagreed with Hardin. In an interview with Levi (2010), she recounted that the first time she heard Hardin she “was somewhat taken aback” because her and Vincent’s work proved Hardin was wrong.⁴

Elinor Ostrom and other social scientists challenged the frame set by Hardin by asking two foundational sets of questions: First, how well does the tragedy of the commons allegory describe reality? Is it a useful theory for making predictions about real-world behavior of individuals sharing common-pool resources? Does it describe a normal or exceptional situation? Does it provide a useful basis for choosing or designing regulatory solutions? Second, does the binary choice between government command-and-control regulation and private property-enabled markets reflect the full range of options? Are there alternative (bottom-up) institutions and/or means for collective action (Frischmann 2013, 390)?

To answer the first set of questions, it may be *convenient* to work within the confines of Hardin’s shepherd allegory, because doing so makes analysis tractable. As Elinor Ostrom explained (E. Ostrom 2007, 15183):

Situations characterized by [Hardin’s] assumptions, in which individuals independently make anonymous decisions and primarily focus on their own immediate payoffs, do tend to overharvest open-access resources. Researchers have repeatedly generated a “tragedy of the commons” in experimental laboratories when subjects make independent and anonymous decisions in a common-pool resource setting.

The allegory, however, is reductionist and distorting. It includes a series of assumptions with respect to both resources and resource management that severely limits its generalizability. Simply put, Hardin’s description of the tragedy of the commons ruled out—by assumption—the possibility that people might communicate and find ways to cooperate. Again, as Elinor Ostrom explained (E. Ostrom 2007, 15183):

Making one small change . . . in the structure of laboratory experiments, a change that is predicted by game theory to make no difference in the predicted outcome, has repeatedly had major impacts on interactions and outcomes. Simply enabling subjects to engage in face-to-face communication between decision rounds enables them to approach socially optimal harvesting levels rather than severely overharvesting the commons. In the face-to-face discussions, participants tend to discuss what they all should do and build norms to encourage conformance.

Elinor Ostrom also criticized reliance on the rational actor model at the heart of Hardin’s allegory when analyzing collective action and social dilemmas (E. Ostrom

⁴For more details on Elinor Ostrom’s framework, useful starting points are Aligica and Boettke (2009) and Tarko (2017).

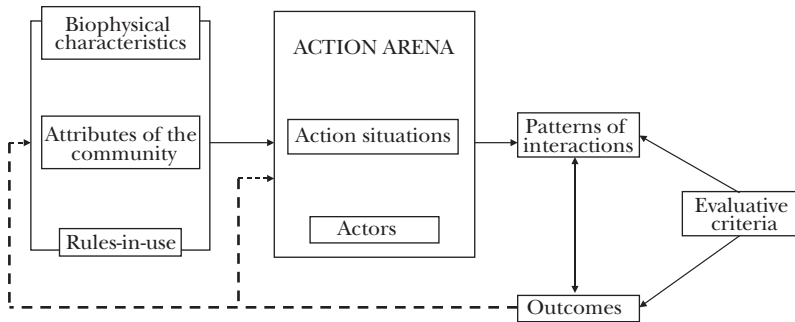
2000). After establishing a series of “well-substantiated facts” about human behavior based on extensive fieldwork, she concluded: “I believe that one is forced by these well-substantiated facts to adopt a more eclectic (and classical) view of human behavior” (E. Ostrom 2000, 141). She then developed a “second-generation model of rationality” in which humans are “complex, fallible learners who seek to do as well as they can given the constraints that they face and who are able to learn heuristics, norms, rules, and how to craft rules to improve achieved outcomes” (E. Ostrom 1998, 9). The second-generation model of rationality predicts that reciprocity, reputation, and trust as “core relationships” can lead to increased net benefits (13). This theoretical model identifies “individual attributes” that are particularly important in explaining behavior in social dilemmas. These attributes include “[1] the expectations individuals have about others’ behavior (trust), [2] the norms individuals learn from socialization and life’s experiences (reciprocity), and [3] the identities individuals create that project their intentions and norms (reputation)” (14).

Thus, Elinor Ostrom (1990) rebelled against the distorting reductionism that Hardin’s essay represented—and Hardin was hardly the only culprit. Donning the analytical straitjacket would “lead the analyst to miss what is most important and focus on what is least relevant” (Frischmann 2013, 390). This was especially true when approaching the second set of questions and the feasibility of institutional solutions besides private property-enabled markets and government command-and-control regulation. Commons governance was ignored as a solution because it was presumed to be *the* problem that inevitably leads to ruin.

To explore alternative institutional arrangements, Elinor and Vincent Ostrom, and their colleagues both at the Workshop in Political Theory and Policy Analysis at Indiana University and around the world, advocated “to combine formal approaches, fieldwork and experiments in order to ‘penetrate’ social reality rather than to use formal techniques to ‘distance’ ourselves from it” (V. Ostrom, quoted in Aligica 2009, 5). Thus, in the three decades that followed publication of Hardin’s “Tragedy,” they engaged in rigorous, interdisciplinary social science to diagnose social dilemmas and to understand the commons as a mode of governing access to and use of shared resources. This approach stressed context and was grounded in empirical study. Systematic studies of real communities demonstrated that commons governance works in some contexts and fails in others (E. Ostrom 1990, 2005). Communities may develop their own governance institutions, but communities are still embedded in government and market systems. Recognizing that governance institutions vary across communities and contexts, Elinor Ostrom and colleagues developed a framework illustrated in Figure 1—the Institutional Analysis and Development (IAD) framework (for explanation, useful starting points are Kiser and Ostrom 1982; E. Ostrom 1986, 1994)—that could be used to analyze institutional arrangements and capture their diversity.⁵ To quote Elinor Ostrom, “[t]he IAD

⁵The Social Ecological Systems and Governing Knowledge Commons frameworks build upon the IAD framework (E. Ostrom 2007; Frischmann, Madison, and Strandburg 2014). All three frameworks enable systematic institutional analysis.

Figure 1

Institutional Analysis and Development (IAD) Framework

Source: Adapted from Hess and Ostrom (2007, 44).

framework is designed to enable scholars to analyze systems that are composed of a cluster of variables, each of which can then be unpacked multiple times depending on the question of immediate interest” (E. Ostrom 2010, 646).

Because these clusters of variables are interrelated, researchers can start at the left with the external variables, at the center with the action arena, or at the right with the outcomes. The external variables affect actors and action situations, which “generate patterns of interactions and outcomes that are evaluated by participants in the action situation (and potentially by scholars) and feed back on both the external variables and the action situations” and the actors (E. Ostrom 2010, 647). The many detailed examples using the Institutional Analysis and Development framework are beyond the scope of this paper. As one brief example, consider a lobster fishery. The tragedy of the commons allegory makes assumptions about the biophysical characteristics (depletable), community (independent, self-interested rational actors), and rules-in-use (every fisherman for himself); also, it assumes the only actors are the fishermen and the only relevant collective action problem is the prediction of ruinous competition. Viewed through the IAD lens, the empirical shortcomings of Hardin’s allegory become clear: lobsters are not purely depletable; as a biological matter, they can reproduce and replenish stocks. The relevant community involves more than just the fishermen. Communication and cooperation are feasible. The rules-in-use are more nuanced than everyone for himself (for detailed examination, see Acheson 2003).

Recognizing that people often can cooperate effectively and build institutions to enable sustainable use of shared resources focused scholarly attention on complexity, context, communities, and institutions. This broader field of vision brought informal institutions into view and encouraged their systematic study, and it also improved our understanding of formal institutions by revealing the many ways that government, market, and community institutions depend on one another to be successful. Figuring out how best to successfully cooperate in governing ourselves

and our shared environments remains one of the core questions studied in law, economics, political science, sociology, and many other related fields today.

Two Key Conceptual Mistakes That Further Muddle Hardin's Special Case

As the work of Elinor Ostrom and many others makes clear, the assumptions made in Hardin's (1968) "Tragedy of the Commons" article, highlighted by the shepherd allegory, limit his analysis to a special case. In this section, we go one step further, explaining why Hardin made two basic conceptual mistakes that further distort the usefulness of his case.

First, Hardin confused resources with governance. In his shepherding allegory, for example, the relevant resource is a pasture, and the relevant governance is open-access sharing: as the allegory begins, "Picture a pasture open to all." To describe commons as the resource subject to tragedy is a category error. Commons are *not*, and should not be conflated with, resources. They are neither common-pool resources nor public goods; these types of sharable goods may, however, be governed as or within commons. Instead, commons are a form of resource governance where members of a community share resources on terms set by the community. Thus, commons "applies to resources, and involves a group or community of people, but commons does not denote the resources, the community, a place, or a thing. Commons [are] the institutional arrangement of these elements" (Frischmann, Madison, and Strandburg 2014, 2). Unfortunately, many people describe a commons a shared resource subject to tragedy. This perpetuates Hardin's conceptual mistake.

Second, Hardin conflated two different governance systems. He used the term "commons," but he limited his analysis to the consequences of *only one* mode of governance, open-access sharing. Yet these are quite different, and the differences matter (Frischmann 2012, 8). *Open access* implies no ownership or property rights. No individual or institution has the right to exclude others from the resource. Hence, all who want access can get access, typically for free. By comparison, *commons* involve some form of communal ownership (community property rights, public property rights, joint ownership rights). As a consequence, access to the resource is restricted to the members of the relevant community, under more or less restrictive conditions, and nonmembers can be excluded. In other words, *open access* differs from *commons* in several ways: in terms of *ownership* (none versus communal/group), *definition of community* (public at large versus a more narrowly defined and circumscribed group with some boundary between members and nonmembers), and *degree of exclusion* (none versus exclusion of nonmembers).

These distinctions are important for understanding different institutions and how social arrangements operate at different scales. By making the assumptions that he did, Hardin (1968) locked himself into the analysis of a special case and significantly underestimated the power of commons as an efficient form of governance.

Extensions: Infrastructure and Knowledge

The tragic dilemma at the core of Hardin's allegory has been identified and discussed for a wide range of different resources. Much of the early work focused on natural resources like fisheries and other typically common-pool resources. It has also received renewed attention in immigration debates (for example, Normadin and Valles 2015). But not surprisingly, the dilemma arises with many human-made resources too. Some are common-pool resources subject to congestion and potential deterioration like roads and other infrastructure, while others are public goods subject to free-rider concerns like ideas and other knowledge resources. In these settings, there can also be an inclination toward a Hardin-style bias to believe that the relevant collective action problems (1) can be diagnosed in terms of ruinous competition and (2) can be addressed only by direct government mandates and/or government-enforced property rights. Such bias leads analysts to undervalue the usefulness and workability of commons governance over these resources by the relevant community. Here, we offer a brief and selective discussion of these topics, with an emphasis on how interdisciplinary research in these areas is moving past the basic tragedy of the commons model.

Infrastructure Commons

Infrastructure resources are often managed in an openly accessible manner that gives rise to possibilities that economists have likened to Hardin's tragedy of the commons.⁶ For example, individual users rationally use toll-free highways at a rate and in a manner that maximizes private gains but disregards the effects on other users or, more generally, the sustainability of the resource. If each individual acts in such a fashion, aggregate consumption may lead to congestion costs from crowding, increased waiting time in queues, slower service, pollution, noise, reduced quality of service due to increased interruptions of service, and accelerated depreciation and depletion of the shared infrastructure (Frischmann 2012).

The basic economic model of congestion, like Hardin's (1968) tragedy of the commons, assumes homogeneous uses (Vickrey 1969; Arnott, de Palma, and Lindsey 1993). The shared meadow is used for grazing sheep (not for grazing other animals or for other activities); the shared highway is used to complete trips (in more or less identical vehicles). When considering homogeneous use, economists utilize a congestion cost function that relates the marginal social cost of resource use (like feeding sheep or completing a trip) to utilization rates (traffic) and resource capacity (like acreage or number of lanes). Such congestion is called "anonymous crowding," because the determinants of crowding are utilization and facility size, and attributes of individual users play no part in the equation (Cornes and Sandler 1996, 355). However, complications arise as heterogeneous users and uses are incorporated into economic models (Cornes and Sandler 1996): for example, variance

⁶Unlike Hardin's pasture, most infrastructure resources are human-made, and that gives rise to a host of supply-side issues, which we leave aside for the sake of brevity.

in capacity consumption rates and cross-crowding between uses. To illustrate cross-crowding, Frischmann (2012) extends Hardin's shepherd allegory to include different livestock, assuming sheep, donkeys, and buffalo graze differently and also positing that "sheep and buffalo . . . fight each other." For roadways, a similar extension might involve cars, mass-transit buses, and trucks.

Heterogeneity affects the analysis of costs and benefits and is relevant to diagnosing congestion problems and comparing solutions. When crowding is no longer anonymous, discriminating among uses becomes a regulatory option to consider. In addition, a standard response of modern economists to congestion would be to use some form of congestion pricing to encourage users with heterogeneous values of traveling by car at certain times to sort themselves—a policy choice that goes unconsidered in Hardin (1968).

There is also a case that certain infrastructural resources ought to be managed openly, because doing so may generate public goods and positive externalities or positive scale returns—greater social value with greater use of the resource (Frischmann 2012; Frischmann and Hogendorn 2015). Rose (1986) called this the "comedy of the commons." Rose (1986, 769–70) used road systems to illustrate and explained how commerce enabled by roads is an

interactive practice whose exponential returns to increasing participation run on without limit. . . . Through ever-expanding commerce, the nation becomes ever-wealthier, and hence trade and commerce routes must be held open to the public, even if contrary to private interest. Instead of worrying that too many people will engage in commerce, we worry that too few will undertake the effort.

Commerce generates private value that is captured by participants in economic transactions, as buyers and sellers exchange goods and services, but it also generates social value that is not easily observed and captured by participants. Examples include the value associated with traveling to visit friends and relatives or traveling for recreation, as well as the value of widespread attendance at civic events—knowledge exchange, socialization, and acculturation. If open travel creates positive externalities, society may find diverse ways to take this into account as it considers how to manage access to roads. Frischmann (2012) extends the point to a variety of other infrastructural resources, ranging from basic research to the internet.

The Public Domain and Knowledge Commons

The connection from intellectual property to the tragedy of the commons has been made explicit by a number of writers. Carrol, Ciscil, and Chisholm (1979, 611) appear the first to refer to copyright law as a means for dealing with the tragedy that seems to also plague intellectual commons. Yet ideas are public goods, not common-pool resources. Thus, using and overusing ideas (or works of art) may, in special cases, reduce their value (Landes and Posner 2003, 487) but does not congest or deplete them. Unconstrained consumption seems good—*the more, the merrier* (Rose 1986; see also Merton 1988)—and even just (as discussed in Gosseries,

Marciano, and Strowel 2008) rather than bad or wrong. If an intellectual resource, such as an idea, is openly accessible to all, then everyone who can profitably make use of it will do so. But there's a catch. Ideas are products of human intellect; they require investment of time, effort, and capital. Unconstrained consumption by free riders presents a risk for potential investors, who may struggle to recover a sufficient return on their investment and may underinvest as a result. Thus, tragic underproduction of intellectual resources appears to be a social dilemma that mirrors Hardin's tragedy of the commons. Avoiding cultural, technological, and scientific stagnation seems to require collective action.

Many approaching this problem assume Hardin's (1968) two options: direct government intervention (via public funding) or privatization (via intellectual property-enabled markets). To be clear, government funding and intellectual property are incredibly important drivers of socially valuable knowledge production. However, one can make a case that much or even most of humanity's intellectual resources have been generated and shared within open-access and community-based commons, often without government subsidy and outside of intellectual property-mediated markets. The free-rider allegory myopically presumes tragedy, leading people to believe that free riding is necessarily harmful and needs to be eliminated (Lemley 2005). In fact, the opposite is often true. Free riding is pervasive and is often a beneficial feature, rather than a bug, of our economic, cultural, and social systems (Ramello 2011; Frischmann 2012; Lobel 2013). Since at least Schumpeter (1934), the creative process has been likened to a recombinant process in which (open) access to previously created knowledge plays a crucial role, fueling progress and driving the combinatorial process of knowledge accumulation that fosters economic growth. This perspective emphasizes the positive externalities characterizing knowledge production and the role of commons governance (Weitzman 1998; Marchese et al. 2019), including the role of the knowledge commons and rules governing the public domain.

Knowledge commons refers to the institutionalized community governance of the sharing and, in many cases, creation and curation of a wide range of intellectual and cultural resources (Frischmann, Madison, and Strandburg 2014). Examples include the scientific research commons, including data, literature, and research materials (Reichman, Uhler, and Dedeurwaerdere 2016); intellectual property pools (Madison, Frischmann, and Strandburg 2010); open-source computer software projects (Schweik and English 2012); Wikipedia (Hoffman and Mehra 2009; Safner 2016); "jamband" fan communities (Schultz 2006); and highly specialized technical knowledge like the Cornish steam engine (Nuvolari 2004). Using the Ostrom-inspired Governing Knowledge Commons framework, case studies examine many governance issues, including interactions with intellectual property, government subsidies, and regulation (Frischmann, Madison, and Strandburg 2014; Strandburg, Frischmann, and Madison 2017; Sanfilippo, Frischmann, and Strandburg forthcoming). For example, rare disease research consortia must address numerous governance challenges, including allocating research funding, authorship credit, and other rivalrous resources; overcoming

potential “anticommons”⁷ dilemmas arising from researchers’ incentives to hoard access to patients and their data; maintaining privacy, security, and the trust of patients and their families; reducing transaction costs of cooperation between widely dispersed researchers; and managing interactions with outsiders, such as pharmaceutical companies.

Other researchers have focused on the governance of the public domain, which is the incredibly capacious set of ideas, facts, and many other intellectual resources that are openly accessible by default to everyone (Litman 1990; see also Posner 2005). As an example of work in this area, a rich legal literature explores categories related to public domain, such as the semi-commons constructed within intellectual property systems and the creative commons constructed with intellectual property licenses (for a detailed survey, see Benkler 2014).

Social demand for trusted governance of shared knowledge resources, ranging from medical data to algorithmically generated intelligence, is growing (Frischmann and Selinger 2018), even as public trust in governments and markets as sources of governance seems tenuous. Now, more than ever, we need to explore whether, when, and how commons governance can scale.

Conclusion

Hardin’s (1968) ultimate legacy is not really about his analysis of the tragedy of the commons, which was relatively trivial given already available economic tools, nor is it about his analysis of commons, which focused only on a narrow special case. Hardin contributed a catchphrase that caught the prevailing winds of public discourse and drew attention to the governance of shared resources. In the end, Elinor Ostrom’s interdisciplinary, international, and systematic analysis of commons governance is and should be the abiding legacy of the tragedy of the commons.

⁷Michael Heller (1998) coined the term “anticommons.” He argued that too much private property could lead to underuse and waste of resources, with effects as tragic as the lack of property rights described by Hardin (1968). Heller and Rebecca Eisenberg explored the potential tragedy of the anticommons in biomedical research (Heller and Eisenberg 1998). Buchanan and Yoon (2000) developed a formal economic model of anticommons. The anticommons concept may offer a justification for fair use and other copyright exceptions (Depoorter and Parisi 2002; Parisi, Schulz, and Depoorter 2005).

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