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OPTIMAL PROPERTY RIGHTS FOR EMERGING NATURAL RESOURCES: A CASE STUDY ON OWNING ATMOSPHERIC MOISTURE

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Abstract

*This Article critically examines the design of property rights for emerging natural resources—naturally occurring substances that humans have only recently come to be able to exploit viably—through a case study of how the fifty states allocate ownership in, and regulate the use of, atmospheric moisture, an issue that has emerged in the context of weather modification (particularly cloud seeding). Building on the surprising finding that legislative declarations of state ownership have not resulted in greater regulatory control or other substantial restrictions on private use, this Article highlights a dimension of property rights design that has yet to receive concerted scholarly attention: the relative ease of future transitions—transitions both in ownership and in control mechanisms. This Article explains how state property facilitates easier and more holistic transitions and argues that state property can be an optimal allocation of emerging natural resources, because uncertainty surrounding the viability of present uses of the resource suggests that property rights arrangements may need to be changed in the foreseeable future. More broadly, the case study reveals how state property—properly stripped of its undeserved associations with socialism—still has an important role to play in property rights literature.***

Introduction

Emerging natural resources are naturally occurring substances that, while previously not considered valuable, are becoming increasingly subject to economically viable exploitation because of

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technological advances or socioeconomic change.[1] The question of who is to own such resources inevitably accompanies their newfound value, particularly for resources that could not be meaningfully captured, modified, or utilized before recent technological innovations. For example, the advent of carbon sequestration and heat mining has focused renewed attention on the property rights to the space beneath the land surface.[2] Similarly, the increased policy emphasis on renewable energy generation has generated legislative and regulatory actions concerning the rights to sunlight and wind[3]—actions up to and including nationalization.[4] Several generations ago, amid the post-WWII technological euphoria over weather modification, there appeared a whole host of law review articles—including one aptly titled "Who Owns the Clouds?" published in the inaugural volume

1. One good example is unconventional petroleum deposits. Manifestations previously costly and/or difficult to extract are labeled "emerging" natural resources when high oil prices and technological breakthroughs in drilling and refining significantly enhance the economic potential of their extraction. Frank J. Atkins & Alan J. MacFadyen, *A Resource Whose Time Has Come? The Alberta Oil Sands as an Economic Resource*, 29 ENERGY J. 77, 77–78 (2008) (describing, in 2008, Canadian oil sands as "emerging resources"); Joseph L. Fisher, *Natural Resources and Technological Change*, 29 LAND ECON. 57, 61–62 (1953) (discussing shale oil as an "emerging natural resource" in 1953). The term has also been used to described natural resources in the Arctic that may become exploitable upon the melting of the Arctic ice cap. Thomas Au et al., *The Arctic Ice Melt: Emerging Resources, Emerging Issues*, 38 CAN.-U.S. L.J. 195, 195 (2013); Erika Lennon, *A Tale of Two Poles: A Comparative Look at the Legal Regimes in the Arctic and the Antarctic*, 8 SUSTAINABLE DEV. L. & POL'Y. 32, 36 (2008).

2. Owen L. Anderson, *Geologic CO_2 Sequestration: Who Owns the Pore Space?*, 9 WYO. L. REV. 97, 99–109 (2009); John G. Spranking, *Owning the Center of the Earth*, 50 UCLA L. REV. 979, 1030–31 (2008); FRED BOSSELMAN, JIM ROSSI & JACQUELINE LANG WEAVER, ENERGY, ECONOMICS AND THE ENVIRONMENT 48–58 (Foundation Press 2000). Carbon sequestration is the removal of carbon dioxide from the air and subsequent storage of it in deep subsurface layers, to reduce greenhouse gas in the atmosphere. Anderson, *supra*, at 97–98. Heat mining involves injecting water deep underground where it is then boiled by the natural underground heat. The resulting steam can then be used to propel electricity-generating turbines. John G. Spranking, *supra*, at 1030–31; BOSSELMAN, ROSSI & WEAVER, *supra*, at 48–50.

3. For a discussion of the policy considerations and proposed statutes relating to this "right" to sunlight and wind, see Troy A. Rule, *Property Rights and Modern Energy*, 20 GEO. MASON L. REV. 803, 823–26 (2013); David E. Missirian, *Let the Sun Shine In: An Examination of Solar Easements and a Proposed Statute*, 41 REAL EST. L.J. 303 (2012); Sara C. Bronin, *Solar Rights*, 89 B.U. L. REV. 1217, 1222–25 & 1237–50 (2009); BOSSELMAN, ROSSI & WEAVER, *supra* note 2, at 36–40.

4. Heilong jiang sheng qihou ziyuan tance he baohu tiaoli [Heilong Jiang Province Regulation on Climate Resources Survey and Protection], art. 7 (promulgated by Standing Comm. Heilong Jiang People's Cong., June 14, 2012, effective Aug. 1, 2012) (P.R.C.). For critical discussion of this episode of regulating emerging natural resources, see Jianlin Chen & Jiongzhe Cui, *Property Rights Arrangement in Emerging Natural Resources: A Case Study of China's Nationalization of Wind and Sunlight*, 27 COLUM. J. ASIAN L. 81 (2013).

of the Stanford Law Review in 1948[5]—examining the ownership of atmospheric moisture.[6]

The prominence of the issue of ownership is unsurprising, given the copious literature addressing how profoundly the various forms of property rights arrangements can affect the efficiency and redistributive considerations of resource utilization.[7] In particular, scholars have claimed that implementing an appropriate property rights regime is essential for avoiding both over-exploitation (the tragedy of the commons[8]) and under-utilization (the tragedy of the anticommons[9]). The same literature has also explored how the control mechanisms associated with a property rights regime—mechanisms that may take the form of informal norms or formal regulations—are crucial factors in whether the outcome is "comedy" or "tragedy."[10] Underpinning this rich discourse is a twofold idea: first, that it is possible to specify a combination of ownership and control mechanisms that will be optimally tailored to the characteristics of the resource; and, second, that we should try to implement that combination, notwithstanding the challenges that

5. *Who Owns the Clouds?*, 1 STAN. L. REV. 43 (1948).

6. *E.g.*, Donald D. Stark, *Weather Modification: Water. Three Cents per Acre-Foot?*, 45 CAL. L. REV. 698, 703–04 (1957); Derek H. Hene, *The Legal Aspects of Rainmaking*, 19 MOD. L. REV. 285, 285 (1956).

7. *See infra* Part II.A & Part II.B.

8. The tragedy of the commons occurs when individuals, in pursuit of their self-interest, overexploit communally shared resources with little consideration of the costs of their actions because they are borne by other individuals and society in general. Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968). For more recent exposition and applications, see Gerd Winter, *Rationing the Use of Common Resources: Problems of Design and Constitutionality*, *in* THE REGULATORY STATE: CONSTITUTIONAL IMPLICATIONS 129, 137 (Dawn Oliver, Tony Prosser & Richard Rawlings eds., 2010); MOORE MCDOWELL ET AL., PRINCIPLES OF ECONOMICS 337–43 (2d European ed. 2009); ROBERT COOTER & THOMAS ULEN, LAW AND ECONOMICS 147–50 (4th ed. 2004).

9. The tragedy of the anticommons occurs when multiple entities hold rights of exclusion to a scarce resource and transaction costs prevent effective coordination, leading to holdout and the resulting underuse of the resource. Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621, 624–26 (1998). For more recent exposition and application, see Lea Kosnik, *The Anticommons and the Environment*, 101 J. ENVTL. MGMT. 206 (2012); Fiona Murray & Scott Stern, *Do Formal Intellectual Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anticommons Hypothesis*, 63 J. ECON. BEHAV. & ORG. 648, 654–56 (2007).

10. Gregg W. Kettles, *Formal Versus Informal Allocation of Land in a Commons: The Case of the MacArthur Park Sidewalk Vendors*, 16 S. CAL. INTERDISC. L.J. 49, 77–92 (2006); Hanoch Dagan & Michael A. Heller, *The Liberal Commons*, 110 YALE L.J. 549, 581–602 (2001); ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 15–21 (1990). *See infra* Part II.B.

both inertia[11] and interest group politics[12] may present to its adoption.

But what happens if the utilization patterns of the resources are in transition, as is typical for emerging natural resources? By definition, emerging natural resources are harnessed by recently developed and still-evolving technologies. This state of flux, coupled with uncertainties concerning the effects—both intended and unintended—that commonly plague new technologies,[13] makes it impossible to conclusively establish the resource characteristics that would otherwise form the factual basis for the normatively optimal combination of ownership and control mechanisms. How should one approach the issue of property rights under such uncertainty?

This Article examines the optimal design of property rights for emerging natural resources via a case study on how weather-modification activities are regulated among the fifty states. Given the profound effects of weather on human subsistence and human activity, attempts to influence the weather are virtually universal across human culture, ranging from the fascinating diversity of tribal ritual to the intriguing experiments of early industrial-age pseudoscience.[14] As technological advancements have at once increased our surveillance of weather patterns and enhanced our capacity to alter the physical environment, the harnessing of atmospheric moisture—the natural resource primarily targeted by weather-modification technologies—has finally begun moving from ritual to reality.[15]

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11. *See* Holly Doremus, *Climate Change and the Evolution of Property Rights*, 1 U.C. IRVINE L. REV. 1091, 1109–10 (2011); Jonathan Remy Nash & Stephanie M. Stern, *Property Frames*, 87 WASH. U. L. REV. 449, 479–92 (2010); Heller, *supra* note 9, at 659.

12. Saul Levmore, *Two Stories About the Evolution of Property Rights*, 31 J. LEGAL STUD. 421, 433 (2002); Katrina Miriam Wyman, *From Fur to Fish: Reconsidering the Evolution of Private Property*, 80 N.Y.U. L. REV. 117, 123–25 (2005).

13. *See, e.g.*, Marc Allen Eisner, *Institutional Evolution or Intelligent Design: Constructing a Regulatory Regime for Nanotechnology*, *in* GOVERNING UNCERTAINTY: ENVIRONMENTAL REGULATION IN THE AGE OF NANOTECHNOLOGY 28, 29–42 (Christopher J. Bosso ed., 2010) (nanotechnology); Wolfgang van den Daele, *Legal Framework and Political Strategy in Dealing with the Risks of New Technology: the Two Faces of the Precautionary Principle*, *in* THE REGULATORY CHALLENGE OF BIOTECHNOLOGY 118, 118–20 (Han Somsen ed., 2007) (genetic modified organisms).

14. WILLIAM R. COTTON & ROGER A. PIELKE SR., HUMAN IMPACTS ON WEATHER AND CLIMATE 3 (Cambridge University Press 2d ed. 2007); Ray Jay Davis, *Atmospheric Water Resources Development and International Law*, 31 NAT. RESOURCES J. 11, 11–12 (1991); Joel P. Bartlett, *Environmental and Legal Considerations in Weather Modification Activities in the Northern Sierra Nevada*, 12 WATER, AIR, AND SOIL POLLUTION 29, 29 (1979).

15. Some of the most important technologies include satellite and radar meteorological tracking and computerized analysis of weather data. Harold D. Orville, *Weather Modification*, *in* HANDBOOK OF WEATHER, CLIMATE, AND WATER: DYNAMICS, CLIMATE, PHYSICAL METEOROLOGY, WEATHER SYSTEMS, AND MEASUREMENTS 433, 444–47 (Thomas D. Potter & Bradley R. Colman eds., 2003); Chunglin Kwa, *The Rise and Fall of Weather Modification*, *in* CHANGING THE

It has been a long process. Concerted attempts at weather modification began shortly after World War II. For the most part, the United States led the way, on both the public and the private fronts, as large-scale, government-sponsored cloud-study programs appeared at the same time as early corporate attempts at viable commercial cloud-seeding.[16] Since the 1950s, there have been numerous legislative and regulatory responses (at both state and federal levels) and a handful of judicial decisions,[17] some of which led to explicit legal pronouncements on the property rights to atmospheric moisture.[18]

Drawing on this relatively detailed legislative and regulatory experience, which has been quite lengthy in comparison to other modern emerging natural resources, this case study explores the relationship between the allocation of property rights—whether legislatively instituted or judicially declared—and the corresponding regulatory controls on weather-modification activities. The case study makes two notable findings. First, states differ widely in their regulatory approaches, and no dominant approach has emerged. This situation, hardly unexpected, reflects the particular challenges posed by emerging natural resources. Without a consensus about the actual consequences of the regulated activities, it is only natural to expect a high degree of regulatory experimentation among the states, particularly in the absence of overarching federal law or regulation.[19]

Second, and more surprisingly, the express declaration of state ownership of—or sovereign rights over[20]—atmospheric moisture in

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ATMOSPHERE: EXPERT KNOWLEDGE AND ENVIRONMENTAL GOVERNANCE 135, 143 (Clark A. Miller & Paul N. Edwards eds., 2001).

16. COTTON & PIELKE, *supra* note 14, at 67–72; CHARLES F. HUTCHINSON & STEPHANIE M. HERRMANN, THE FUTURE OF ARID LANDS—REVISITED 47–48 (2008); Kwa, *supra* note 15, at 138. For a good historical account on the development of weather modification, see James R. Fleming, *The Pathological History of Weather and Climate Modification: Three Cycles of Promise and Hype*, 37 HIST. STUD. PHYSICAL & BIOLOGICAL SCI. 3 (2006).

17. *Infra* Part IV.A.

18. *Infra* Part IV.B.

19. *Infra* Part IV.A.1.

20. In the scholarly literature, state sovereign rights over a resource are often equated or used interchangeably with state ownership, as the establishment of state sovereign rights will grant the state exclusive control over the resource and preclude the possibility of private ownership (save for licenses or other state-granted permission). *See, e.g.*, Deepa Varadarajan, *A Trade Secret Approach to Protecting Traditional Knowledge*, 36 YALE J. INT'L L. 371, 388–89 (2011); ELENA MERINO BLANCO & JONA RAZZAQUE, GLOBALIZATION AND NATURAL RESOURCES LAW: CHALLENGES, KEY ISSUES AND PERSPECTIVES 9 (Edward Elgar 2011); TERENCE DAINTITH, FINDERS KEEPERS? HOW THE LAW OF CAPTURE SHAPED THE WORLD OIL INDUSTRY 305–06 (2010); Carole Nakhle, *Iraq's Oil: Dangers and Rewards*, 8 INTERNATIONAL ENERGY L. REV. 263, 264 (2010); Yinka Omorogbe & Peter Oniemola, *Property Rights in Oil and Gas under Domanial Regimes*, *in* PROPERTY AND THE LAW IN ENERGY AND NATURAL RESOURCES 115, 120–24 (Aileen

a state's statute or constitution has no observable effects on that state's regulatory regime. Contrary to the views of some scholars that nationalization invariably leads to heavier state intervention and larger claims to the economic surplus,[21] state ownership has not resulted in either greater regulatory control or more redistribution than that in states that have not laid claim to atmospheric moisture.[22] By contrast, judicial decisions granting *private* rights over atmospheric moisture have had a constraining effect on the regulatory regime, as seen in the unique regulatory provisions of those states.[23]

Building on these findings, this case study highlights an unduly neglected dimension of the design of property rights: the relative ease of future transitions, whether on the ownership plane or on the regulatory one. Although no scholar would ever claim that resource-utilization patterns are static (given the numerous scholarly studies of how and why property rights evolve[24]), discussions about optimal property rights have consistently focused on the compatibility of rights with current patterns of resource utilization, while

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McHarg et al. eds., 2010). *See also* Dale D. Globe, *Three Cases/Four Tales: Commons, Capture, the Public Trust and Property in Land*, 35 ENVTL. L. 807, 838–39, 847–53 (2005) (discussing how the courts' confusing/inconsistent categorization of state's power to regulate wildlife as "property" and "sovereignty" is due a semantic issue where "ownership" is "simply a shorthand way of describing a State's substantial interest in preserving and regulating . . . the fish and game."). *C.f.*, Ricardo Pereira & Orla Gough, *Permanent Sovereignty over Natural Resources in the 21st Century: Natural Resource Governance and the Right to Self-Determination of Indigenous Peoples under International Law*, 14 MELB. J. INT'L L. 451, 455 n.17 (2013) ("As regards offshore energy resources, coastal states have 'sovereign rights' in the continental shelf and functional jurisdiction for purposes of exploring and exploiting, but not ownership rights."); Jonnette Watson Hamilton & Nigel Bankes, *Different Views of the Cathedral: The Literature on Property Law Theory*, *in* PROPERTY AND THE LAW IN ENERGY AND NATURAL RESOURCES, *supra*, at 19, 30–31 (discussing the under-theorized connection between sovereignty and property, where there are scholars who equate sovereignty as property, while others see property as following from sovereignty). In the weather modification statutes surveyed, the state's rights to the atmospheric moisture were usually declared via sovereign rights, though North Dakota labelled the provision "extended state ownership of water sovereignty over moisture" while Montana declared "atmospheric waters" as "the property of the state." *Infra* Part IV.B.

21. Gabriela Engler Pinto, *Upstream Oil and Gas Legal Frameworks: Brazil and the United States Compared*, 115 W. VA. L. REV. 975, 997–98 (2013); A. F. M. Maniruzzaman, *The Issue of Resource Nationalism: Risk Engineering and Dispute Management in the Oil and Gas Industry*, 15 TEX. J. OIL, GAS, & ENERGY L. 79, 83-85 (2010). *See* Chen & Cui, *supra* note 4, at 91–92 (discussing the public skepticisms over the purported "nationalization" of wind and sunlight by a Chinese provincial government).

22. *Infra* Part IV.C.

23. *Infra* Part IV.C.

24. *E.g.*, Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. 347, 354–59 (1967); Abraham Bell & Gideon Parchomovsky, *The Evolution of Private and Open Access Property*, 10 THEORETICAL INQUIRIES L. 77, 86–90 (2009); Daniel Fitzpatrick, *Evolution and Chaos in Property Rights Systems: The Third World Tragedy of Contested Access*, 115 YALE L.J 996, 1038–46 (2006); Wyman, *supra* note 12, at 123–25; Levmore, *supra* note 12, at 433; Barry C. Field, *The Evolution of Property Rights*, 42 KYKLOS 319, 335–40 (1989).

neglecting to consider the effects of different initial allocations on future transitions. In one sense, this omission is understandable, given the relatively stable resource-utilization patterns of conventional natural resources. But in the emerging resources context, current uncertainties make future changes almost inevitable. For that reason, any analysis of the optimal allocation of property rights should consider whether that allocation will impede or facilitate the changes that will become normatively desirable as technologies mature and uncertainties are resolved.

Specifically, this Article argues that state ownership—the increasingly neglected child in the property literature[25]—can actually be desirable, because it facilitates future transitions. First, transition to the different property rights regime (the commons, private property, or the anticommons[26]) and control mechanisms (e.g., regulations and taxes) is easier—both legally and politically—when the starting point is state ownership. Second, there is greater chance of a holistic assessment and alignment of property ownership and control mechanisms during a transition from state ownership than from another property rights regime. While it is true that numerous legitimate concerns may be raised about the efficiency and fairness of state ownership,[27] state property nonetheless merits greater scholarly attention, particularly when the resource is an emerging natural resource and when the state has well-functioning governance institutions.

There is a broader point to be made here. This case study of atmospheric moisture, like previous comparative studies of state property across other jurisdictions,[28] shows that continuous and active intervention by government regulators is but one of many approaches that a state may adopt to manage state property. Once stripped of its undeserved association with socialism, state property has an important role to play in the general property rights literature.

This Article is organized into five Parts. Part I engages in a literature review to highlight the unexamined issue of the comparative

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25. *E.g.*, Michael Heller, *Introduction: Commons and Anticommons Reader*, *in* COMMONS AND ANTICOMMONS: VOLUME I xi, xvi (Michael Heller ed., 2009); YORAM BARZEL, ECONOMIC ANALYSIS OF PROPERTY RIGHTS 71 (1989). State property has been more favorably discussed in the context of emerging natural resources. *See, e.g.*, Spranking, *supra* note 2, at 1032–33 (arguing that the mantle, outer core, and inner core should be considered as public land owned by the federal government).

26. *See* Heller, *supra* note 25, at xviii (describing commons, private property and anticommons as the "full spectrum of ownership").

27. *See infra* Part V.C.

28. *E.g.*, Bruce R. Huber, *The Durability of Private Claims to Public Property*, 102 GEO. L.J. 991, 994 (2014); Chen & Cui, *supra* note 4, at 111–19.

ease of transition out of different property rights arrangements. Part II lays out the overall context of the case study: it first outlines the historical development and current status of weather-modification activities, then surveys the existing scholarly literature on the ownership of atmospheric moisture. Part III presents the findings of this case study, notes the diverse array of regulatory approaches in the fifty states, and examines the relationship between property rights assignments and regulatory regimes. Part IV addresses the indifferent regulatory effect of state ownership and explains how state ownership facilitates easier and more holistic transitions, and thus how state ownership may be a desirable property rights arrangement for emerging natural resources under certain specified conditions. Part V discusses the broader implications of the undeservedly chastised and/or neglected idea of state property ownership within the property rights literature.

I. OPTIMAL PROPERTY

This Part briefly surveys the burgeoning literature on the design of property rights for optimal resource utilization. In four Sections, it examines the classic literature of commons and anti-commons; the role of resource characteristics and control mechanisms on the desirability of the outcome; the existing discussion of transitions; and, finally, how emerging natural resources highlight the previously unexamined issue of relative ease of transition.

A. Commons and Anticommons

The concepts of commons and anticommons are now indispensable for almost any discussion of optimal property rights over a given resource.[29] The concept of commons[30] took off with Garrett Hardin's seminal "The Tragedy of the Commons."[31] Hardin, through the example of a public-access pasture, examined the potential pitfalls of resources that are subject to communal ownership. Hardin's central insight is elegantly simple: because any individual

29. *See* Lee Ann Fennell, *Common Interest Tragedies*, 98 NW. U.L. REV. 907, 907–09 (2004) (giving a concise intellectual history on the rise and entrenchment of the two concepts in legal discourse).

30. The concept of the commons, and the recognition that such resources are susceptible to overexploitation, predates Hardin's article. *See, e.g.*, H. Scott Gordon, *The Economic Theory of a Common-Property Resource: The Fishery*, 62 J. POL. ECON. 124 (1954).

31. Hardin, *supra* note 8.

herdsman will retain all the benefits of grazing his herd on the pasture but bear only a fraction of the costs of overgrazing, the pasture will almost inevitably be overexploited, and will collapse.[32] The canonical contemporaneous example of such a dynamic is overfishing in international waters. Depletion of fish stocks and the collapse of major international fisheries remain significant challenges today.[33]

But, as the following section I.B. will discuss, the fact that a resource is communally owned does not necessarily imply that it will be used inefficiently. Nonetheless, the stark prospect of unrestrained multi-party exploitation prompted many scholars to prescribe privatization as a virtual panacea to the problem of overexploitation.[34] Through the parceling out and creation of private property in the underlying resource, each owner will now arguably have incentive to conserve the resource for optimal utilization.

In certain situations, however, privatization can be suboptimal, a point Michael Heller recognized in a pioneering article that launched the concept of the anticommons.[35] Anticommons, as its name suggests, is the polar opposite of the commons: it consists of resources over which multiple entities hold rights of *exclusion*. Given the frequently high transaction costs necessary for effective coordination among these multiple rights holders, as well as the invariable holdout problems, resource underuse is the bane of such an arrangement of property rights. Heller's lead example, the fragmented regulatory regimes of post-Soviet Russia storefronts, showed how the anticommons could lead to as many "tragic" outcomes as does Hardin's commons.[36] Later scholars, applying and extending Heller's insights, have brought the anticommons to bear

32. *Id.* at 1244.

33. Winter, *supra* note 8, at 137; Hope M. Babcock, *Grotius, Ocean Fish Ranching, and the Public Trust Doctrine: Ride 'Em Charlie Tuna*, 26 STAN. ENVTL. L.J. 3, 7–11 (2007); Fikret Berkes, *Native Subsistence Fisheries: A Synthesis of Harvest Studies in Canada*, 43 ARCTIC 35, 40–41 (1990); O. Hertz & F. O. Kapel, *Commercial and Subsistence Hunting of Marine Mammals*, 15 AMBIO 144, 146 (1986).

34. *See* Amy Sinden, *The Tragedy of the Commons and the Myth of a Private Property Solution*, 78 U. COLO. L. REV. 533, 537–38 (2007) (discussing the popularity of privatization as the solution for environmental problems among academics and policymakers since the 1970s); Dagan & Heller, *supra* note 10, at 559–64 (discussing how the tragedy of the commons is commonly used in the literature as a theoretical justification for private property). *See also* Thráinn Eggertsson, *Open Access versus Common Property*, *in* PROPERTY RIGHTS: COOPERATION, CONFLICT AND LAW 73, 75–84 (Terry L. Anderson & Fred S. McChesney eds., 2002) (arguing for a more nuanced distinction between open-access and common property).

35. Heller, *supra* note 9, at 624–26.

36. *Id.* at 627–59.

on the issues of intellectual property (patents in particular[37]) and post-disaster reconstruction.[38]

B. Comedy and Tragedy

Commons and anticommons are associated with the tragedies of overexploitation and underutilization, usually (but not always[39]) in that order. Yet an adverse outcome is not a necessary consequence of adopting either regime. Scholars have identified two scenarios in particular in which commons and anticommons may be desirable.

The first is when the optimal use of a resource is the over- or under-use characteristic of commons and anticommons, respectively. For example, creating an anticommons in land that should be conserved—perhaps by granting veto powers to multiple entities—turns the supposed disadvantage of high transaction costs into a desirable damper on development.[40] Conversely, the public access facilitated by the commons can generate large social and economic benefits when the property in question is crucial to commerce and serves as a socializing network.[41] From a broader perspective, these examples are simply manifestations of the commonsense principle that the optimal property rights arrangement will depend upon the particular characteristics of the natural resource involved.[42]

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37. *E.g.*, Murray & Stern, *supra* note 9; Rosemarie Ham Ziedonis, *Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms*, 50 MANAGEMENT SCIENCE 804 (2004).

38. *E.g.*, Russell S. Sobel & Peter T. Leeson, *Government's Response to Hurricane Katrina: A Public Choice Analysis*, 127 PUB. CHOICE 55 (2006); Mark D. West & Emily M. Morris, *The Tragedy of the Condominiums: Legal Responses to Collective Action Problems After the Kobe Earthquake*, 51 AM. J. COMP. L. 903 (2003).

39. Commons will not be overused but underused if harvesting/capturing of the resources from the commons does not provide any right of exclusion to the harvester/capturer. Anticommons might be overused if the rights of veto are sufficiently costly and the collective action problem of free riders results in insufficient exercise of those veto rights. Heller, *supra* note 9, at 675–78. *See* Fennell, *supra* note 29, at 933–40 (arguing that the dichotomy of overuse and underuse is illusionary given the fluidity in framing the resource in question).

40. Heller, *supra* note 25, at xxiv; Abraham Bell & Gideon Parchomovsky, *Of Property and Antiproperty*, 102 MICH. L. REV. 1, 31–36 (2003).

41. Carol M. Rose, *The Comedy of the Commons: Custom, Commerce, and the Inherently Public Property*, 53 U. CHI. L. REV. 711, 774–81 (1986).

42. Rule, *supra* note 3, at 804–05; DANIEL H. COLE, POLLUTION AND PROPERTY: COMPARING OWNERSHIP INSTITUTIONS FOR ENVIRONMENTAL PROTECTION 130–32 (2002). *E.g.*, Amy R. Poteete & David Welch, *Institutional Development in the Face of Complexity: Developing Rules for Managing Forest Resources*, 32 HUM. ECOLOGY 279 (2004) (discussing how management of different forest resources is affected by the various characteristics of identification risk, resilience, scarcity and abundance, variability and predictability, the viability of storage, and the availability of substitute); Eggertsson, *supra* note 34, at 75 ("The efficiency of property

The second scenario arises where the commons or anticommons is accompanied by control mechanisms that mitigate the core problems of externalities and transaction costs. For example, the community that has access to the commons might develop customs and norms covering resource use that can be efficient alternatives to centralized regulations or privatization.[43] The breakdown of such an informal governance structure, whether due to socioeconomic changes altering social dynamics[44] or failed replacement with formal regulation[45], will be detrimental to the resource utilization.[46] On the theoretical front, Hanoch Dagan and Michael A. Heller have proposed a concept of the "liberal commons." Through control mechanisms, the liberal commons seeks to maximize efficiency and optimize the redistribution of resources owned by multiple parties. The individual control mechanisms deployed, such as restrictions on overuse, procedural safeguards on collective decision-making, and right of first refusal over exit, are designed to secure three core values: individual dominion, democratic self-governance, and cooperation-enhancing exit.[47] In the same vein, the anticommons's holdout problem may be mitigated by informal management mechanisms that encourage cooperation and foster other communitarian values among the rights holders.[48]

Again, the above simply reflects the general principle that the strengths of any particular proposed property rights arrangement can be undermined (and its weaknesses mitigated) by control mechanisms governing use of the property. For example, private

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rights arrangements is situation-specific. . . . [P]roperty rights are costly to institute and operate (enforce), and the costs depend on relative prices, available technologies, physical characteristics of the assets, types of uses, and the general setting (the institutional environment).").

43. OSTROM, *supra* note 10, at 15–21. *See* Kettles, *supra* note 10, at 77–92 (arguing—vis-à-vis a field study about the allocation of sidewalk in Los Angeles—that the informal allocation system used by illegal vendors ("first come, first served" rule supplemented by the possibility of established rights through continuous usage) is superior than the formal allocation system for legal vendors administered by the a government-contracted non-profit organization (including lottery and assignment on account of benefits of vendor and surrounding neighborhood)).

44. *See* Fitzpatrick, *supra* note 24, at 1033–37 (discussing how social norms governing resource management may break down due to rise in resource value, influx of outsiders that cannot be excluded, and imposition of competing state governance mechanisms); Shirli Kopelman, J. Mark Weber & David M. Messick, *Factors Influencing Cooperation in Commons Dilemmas: A Review of Experimental Psychological Research*, *in* THE DRAMA OF THE COMMONS 113, 118–44 (Elinor Ostrom ed., 2002) (discussing the various factors affecting cooperation, including culture, group size and heterogeneity, payoff structure).

45. Fitzpatrick, *supra* note 24, at 1011–12; Elinor Ostrom, *Coping with Tragedies of the Commons*, 2 ANN. REV. POL. SCI. 493, 495 (1999).

46. Eggertsson, *supra* note 34, at 84–85.

47. Dagan & Heller, *supra* note 10, at 581–602.

48. Heller, *supra* note 9, at 674.

property is valued for giving the owner the incentive and accompanying freedom to choose the most appropriate form of resource use.[49] But various forms of formal legislative, regulatory, and judicial control,[50] or informal customs and norms,[51] can curtail the freedom and distort the choice. Conversely, the potential problems of externalities and redistribution arising from privatization can also be mitigated by control mechanisms. On a more basic level, Henry E. Smith explained that property rights could be viewed as falling along a spectrum between the poles of "exclusion" (representing the conventional understanding of demarcating property boundaries) and "governance" (representing controls over uses).[52] The "property proper" combines both elements (e.g., the *ad coelum* rule coupled with nuisance, zoning and neighborhood covenants),[53] and the optimal combination depends upon the cost-effectiveness of the respective proxies: one weighs the relative value of achieving informational precision in view of the associated measuring costs, for both demarcating boundaries (exclusion) and restricting use (governance).[54]

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49. Thomas W. Merrill, *The Property Strategy*, 160 U. PA. L. REV. 2061, 2081–89 (2012); Andrew P. Morriss, Roger E. Meiners & Andrew Dorchak, *Homesteading Rock: A Defense of Free Access Under the General Mining Law of 1872*, 34 ENVTL. L. 745, 764–73 (2004).

50. The common law doctrine of nuisance is the most prominent example of judicial control over activities that are deemed to cause a substantial and unreasonable interference with a claimant's land or with a claimant's use of that land. JOHN MURPHY, THE LAW OF NUISANCE 5–7(2010); Bent Ole Gram Mortensen et al., *Environmental Protection Law*, *in* LEGAL SYSTEMS AND WIND ENERGY: A COMPARATIVE PERSPECTIVE 207, 223 (Helle Tegner Anker, Birgitte Egelund Olsen & Anita Rønne eds., 2008). There is a similar concept of neighbor law in civil law. Helle Tegner Anker, Birgitte Egelund Olsen & Anita Rønne, *Wind Energy and the Law: A Comparative Analysis*, 27 J. ENERGY & NAT. RESOURCES L. 145, 159 (2009).

51. Sinden, *supra* note 34, at 548; OSTROM, *supra* note 10, at 15–21.

52. Henry E. Smith, *Exclusion Versus Governance: Two Strategies for Delineating Property Rights*, 31 J. LEGAL STUD. 453, 454–56 (2002). For recent application of this perspective, *see* Lynda L. Butler, *The Governance Function of Constitutional Property*, 48 U.C. DAVIS L. REV. 1687, 1757–67 (2015) (arguing that physical takings should be judicially assessed from both the exclusion and governance strategy perspective); Troy A. Rule, *Airspace in an Age of Drones*, 95 B.U. L. REV. 155, 182–85 (2015) (discussing the exclusion and governance rules in relation to low altitude airspace); Gregory S. Alexander, *Governance Property*, 160 U. PA. L. REV. 1853, 1860–63 (2012) (observing the proliferation of property where governance, rather than exclusion, is the dominant mode of property ownership).

53. Smith, *supra* note 52, at 456.

54. *Id.* at 468–74*; see also* COLE, *supra* note 42, at 8–18 (criticizing the conceptual dichotomy between property regime and regulation, and arguing that all solutions to the tragedy of open access are essentially property-based).

C. Transition and Inertia

The previous Section explained that whether a natural resource's use will be optimal depends upon the compatibility of the form of property ownership, the characteristics of resource utilization, and the accompanying control mechanisms. Implicit in this understanding is that the optimal combination of property ownership and control mechanisms will change when resource-use patterns alter, whether because of technological advances or socioeconomic changes. Commons with negligible control mechanisms is actually an ideal management strategy for fisheries when population density is low and fishing technology is primitive. The switch from commons to private property and/or the introduction of control mechanisms only becomes necessary and desirable when the increased harvesting induced by greater demand from a larger population and facilitated by more efficient fishing methods surpasses the natural rate of reproduction.[55]

The question concerning whether and how such transitions materialize has been the subject of extended theoretical discussion and much empirical investigation. The starting point is Harold Demsetz's claim that private property rights arise when internalization of externalities becomes efficient (usually due to a combination of an increase in the value of the resource and a decrease in the costs of establishing and enforcing the associated rights),[56] and his associated account of how the manifested form of ownership depends upon factors such as economies of scale, negotiating costs, and the characteristics of externalities.[57] Later scholars have enriched Demsetz's account by adducing additional factors that might affect the efficiency of the various possible property rights arrangements, as well as refining the factors introduced by Demsetz.[58]

This optimistic picture, in which efficiency is the main force driving transitions, has been challenged in part by Saul Levmore. In Levmore's more pessimistic view, transitions might equally well be driven by interest groups battling for greater redistribution to

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55. *See* Winter, *supra* note 8, at 137; Babcock, *supra* note 33, at 7–11; Berkes, *supra* note 33, at 40–41; Hertz & Kapel, *supra* note 33, at 146.

56. Demsetz, *supra* note 24, at 350–53.

57. *Id.* at 354–59.

58. *See, e.g.*, Bell & Parchomovsky, *supra* note 24, at 86–90 (arguing that the size and scope of the right are dimensions that should be included for a more complete account); Field, *supra* note 24, at 335–40 (discussing the implication of governance costs); James Graham Lake, *Demsetz Underground: Busking Regulation and the Formation of Property Rights*, 87 N.Y.U. L. REV. 1100, 1131–32 (2012) (discussing the role of exogenous legal constraints, such as the First Amendment protection of speech and laws prohibiting physical violence).

themselves.[59] Given the size, governing scope, and practical capabilities of the modern state, interest-group politics are likely to play at least some role in any present-day transition.[60] At the very least, the presence of significant interest-group dynamics is likely to increase the transaction costs of transition.

Another closely-related issue is the problem of inertia. Once created, a given arrangement of property rights is likely to persist, for numerous mutually reinforcing reasons. Entitlement holders, moved by both material interests and cognitive bias, are likely to resist attempts to weaken or abrogate their existing rights.[61] When the transitions involve concentrated losses to a minority (which is typically the case with transitions away from private property and anticommons) the political resistance is aggravated by interest-group dynamics.[62] Constitutional protection of property, particularly when coupled with an expansive doctrine of regulatory takings, will also impede attempts to modify existing private property rights.[63] On top of this is the general problem of regulatory inertia: regulators often prove unwilling to change or relax rules even when changes in circumstances have rendered those rules inefficient.[64] Thus, institutions created or reassigned to enforce the new property rights arrangement will also tend to resist any changes to the arrangement.[65]

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59. Levmore, *supra* note 12, at 423–33.

60. *Id.*; Wyman, *supra* note 12, at 123–25; *see* Jonathan Remy Nash, *Economic Efficiency Versus Public Choice: The Case of Property Rights in Road Traffic Management*, 49 B.C. L. REV. 673, 731–38 (2007) (arguing that the public choice story provides a better explanation in the context of road traffic management, especially in light of how the state is now the primary provider of transportation network); s*ee also* Stuart Banner, *Transitions Between Property Regimes*, 31 J. LEGAL STUD. 359, 365–70 (2002) (observing how a powerful oligarchy—for example, colonial governments—can overcome the obstacles of collective action and mitigate transition costs when they initiate rearrangement of property rights to advance their interests).

61. *See* Doremus, *supra* note 11, at 1099; Nash & Stern, *supra* note 11, at 479–92.

62. Doremus, *supra* note 11, at 1109; *see* Richard L. Hasen, *Lobbying, Rent-Seeking, and the Constitution*, 64 STAN. L. REV. 191, 226–28 (2012) (highlighting the danger of rent-seeking by well-organized narrow interest groups over the collective actions problem of the general public).

63. Lynda L. Butler, *The Resilience of Property*, 55 ARIZ. L. REV. 847, 887–89 (2013); Doremus, *supra* note 11, at 1100–01.

64. *See, e.g.*, Rule, *supra* note 52, at 198; Ji Lian Yap, *Amending the Statutory Framework for the Registration of Company Charges*, 35 STATUTE L. REV. 261, 277 (2014); Lake, *supra* note 58, at 1133–34; William P. Albrecht, *Regulation of Exchange-Traded and OTC Derivatives: The Need for a Comparative Institution Approach*, 21 J. CORP. L. 111, 123 (1995).

65. Heller, *supra* note 9, at 659.

D. Emerging Natural Resources and the Unresolved Relative Ease of Transition

There is one key topic that scholars have not touched on in their discussions: the relative difficulty of transitions—both from one property rights regime to another and from one regulatory regime to another. It is true that various scholars have identified transitional inertia marking a wide variety of property rights arrangements, from private property[66] to anticommons[67] and commons,[68] and even to private claims on state property.[69] To date, however, no one has done a comparison across property rights arrangements to determine which property rights arrangements are particularly "sticky"—and hence more likely to be inefficiently outdated amid changing circumstances—and which are not.

This omission is understandable; the key concern of the literature is to lay down the optimal property rights arrangement right from the outset. Given that the resource-utilization patterns of conventional natural resources tend to be relatively stable without radical changes in the foreseeable near future, it is simply unnecessary to consider the speculative prospect of future transition when designing the appropriate arrangement of property rights. Thus, the role of transition inertia in the literature is limited largely to either explaining the persistence of inefficient property rights or raising the stakes of the initial property rights arrangement without necessarily implicating the actual choice.

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66. *See* Rule, *supra* note 52, at 197–201 (arguing that creating low-altitude-airspace rights for property owners would place "distinct and appropriate limits" on federal regulatory jurisdiction, which, due to regulatory inertia, is unlikely to adapt effectively to the emerging proliferation of drone technology); Butler, *supra* note 63, at 888–89 (discussing how extending the Takings Clause to regulations provides property owners with both a legal avenue for redress and a focal point for political mobilization); Erika Weinthal & Pauline Jones Luong, *Combating the Resource Curse: An Alternative Solution to Managing Mineral Wealth*, 4 PERSP. ON POL. 35, 42–46 (2006) (arguing that domestic private ownership counteracts the inherent and inevitable governance deficiencies in resource-rich developing countries).

67. *See, e.g.*, Heller, *supra* note 9, at 659 ("Once anticommons property is created, markets or governments may have difficulty in assembling rights into usable bundles. After initial entitlements are set, institutions and interests coalesce around them, with the result that the path to private property may be blocked and scarce resources may be wasted.").

68. *See, e.g.*, Fitzpatrick, *supra* note 24, at 1010–21 (discussing the persistence, albeit imperfect, of customary rights of the local community over common resources in developing countries in the face of formal attempts by the state to reassign property rights).

69. Bruce R. Huber, *The Durability of Private Claims to Public Property*, 102 GEO. L.J. 991, 1033 (2014) (discussing how the popular notion that public access is integral to publicly owned property has contributed to the durability of private claims to public property even where the private claims are by no means legally guaranteed or do not amount to property rights).

With emerging natural resources, however, the issue of future transition is quite salient. By definition, uncertainty about the future use patterns of such resources precludes, for the present, any definitive conclusions about the optimal property rights arrangement. Because changes in the resource-utilization pattern are eminently foreseeable, it seems almost negligent to design property rights for emerging natural resources without considering how the initial arrangement might unduly impede transitions in the near future. Similarly, one might posit that, all else being equal, a property rights arrangement that facilitates an easier or normatively superior[70] transition would be preferable to a "stickier" arrangement of property rights.

The remainder of this Article represents a first take on this issue of transition through a case study on atmospheric moisture. Atmospheric moisture provides a useful case study for assessing the design of property rights in emerging natural resources because it is one of the first modern emerging natural resources and has a legislative and regulatory history now over half a century in the making. Although it is true that all current conventional natural resources were once emerging natural resources, the evolution of property rights over them tends to have stabilized before the rise of the modern regulatory state. Without incorporating the effect and operation of the modern regulatory state,[71] the relevance of the inquiry to the current debate on contemporaneous emerging natural resources would be considerably diminished. Indeed, as discussed in Part III, *infra*, the management of atmospheric moisture usage is primarily via regulatory controls. Only occasionally do explicitly defined property rights over atmospheric moisture supplement such controls.

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70. Space constraints prevent a comprehensive examination concerning what constitutes a normatively superior transition. However, this Article utilizes the case study to argue that a holistic transition involving simultaneous changes to both a property rights arrangement and a control mechanism that is normatively superior to reactionary transitions in which attempted modifications to resource utilizations must occur on the basis of that one dimension—usually the property rights dimension—is going to remain unchanged. *Infra* Part V.B.

71. For discussion about the advent of the modern regulatory state, see Jason M. Solomon, *Law and Governance in the 21st Century Regulatory State*, 86 TEX. L. REV. 819, 821–37 (2008); Craig Bradley, *The Rule of Law in an Unruly Age*, 71 IND. L.J. 949 (1996); John Kay et al., *Regulatory Reform in Britain*, 3 ECON. POL'Y 285, 289–301 (1988).

II. WEATHER MODIFICATION IN CONTEXT

This Part sets out the basic context for the case study in Part III, *infra*, by discussing the historical evolution and present status of weather-modification technologies, and then examining the existing legal discussions of the subject.

A. Background

Human culture is inextricably intertwined with the weather. Civilizations rise and fall with the blessing or curse brought by ever-changing precipitation, temperature, and other climatic elements.[72] Across the globe, the multitude of elaborate ceremonies dedicated to affecting the weather demonstrate both the rich cultural diversity of premodern human societies and the common yearning for influence over the seemingly indomitable and incomprehensible skies.[73] The advent of the Industrial Age saw many attempts to deploy the latest mechanical inventions (rockets, cannons, etc.) in service of weather modification[74] but did little to move beyond pseudo-science.

Only after World War II did real progress begin, as a result of both technological advance and socio-political change. Scientists' understanding of weather dynamics grew significantly, thanks to the availability of precise meteorological data from satellites and radars—data now analyzed almost exclusively by computers.[75] The refinement of aviation technologies also increased our access to the skies and clouds.[76] Similarly, the threat and offensive potential of modified weather in achieving Cold War military objectives, in conjunction with the widespread optimism concerning the future prospect of human dominion over climate, helped spawn large-scale U.S government-sponsored research programs on weather

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72. *See generally* PATRICK D. NUNN, CLIMATE, ENVIRONMENT AND SOCIETY IN THE PACIFIC DURING THE LAST MILLENNIUM (2007); ARIE S. ISSAR & MATTANYAH ZOHAR, CLIMATE CHANGE: ENVIRONMENT AND CIVILIZATION IN THE MIDDLE EAST (2004).

73. For some interesting account on the ritualistic practices around the world, *see* Maria H. Schoeman, *Imagining Rain-Places: Rain-Control and Changing Ritual Landscapes in the Shashe-Limpopo Confluence Area, South Africa*, 61 S. AFR. ARCHAEOLOGICAL BULL. 152, 161–64 (2006); Margaret Cannell, *Signs, Omens, and Portents in Nebraska Folklore*, 13 U. NEB. STUD. LANGUAGE, LITERATURE, & CRITICISM 1, 10–11 (1933).

74. COTTON & PIELKE, *supra* note 14, at 3; Davis, *supra* note 14, at 11–12.

75. Orville, *supra* note 15, at 444–47; Kwa, *supra* note 15, at 143.

76. Don A. Griffith, *Cloud Seeding Modes, Instrumentation, and Status of Precipitation Enhancement Technology*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION 81, 81–103 (Conrad G. Keyes Jr. et al. eds., 2006); *see* Orville, *supra* note 15, at 437.

modification, alongside ample experimentation by private cloud-seeding enterprises.[77]

Notwithstanding the limited advances in the theoretical understanding and practical operation of weather modification,[78] the scale and distribution of weather-modification operations has only continued to grow.[79] Countries as diverse as China, South Africa, Libya, Morocco, Burkina Faso, India, and Australia currently operate government-sponsored weather-modification programs, as do a handful of U.S. states (Utah and Colorado, for instance).[80] Commercial weather-modification operators proudly claim operations in even more jurisdictions.[81] One reason for such proliferation is the potential payoff. The marginal benefit of any additional precipitation, although discounted due to an uncertain causal relationship, is arguably substantial enough (particularly in arid areas) to justify the often high costs of weather modification.[82]

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77. COTTON & PIELKE, *supra* note 14, at 67–72; Fleming, *supra* note 16; Kwa, *supra* note 15, at 137–38.

78. *See* ANDREW S. GOUDIE, THE HUMAN IMPACT ON THE NATURAL ENVIRONMENT: PAST, PRESENT, AND FUTURE 226–27 (6th ed. 2009); Tarek Majzoub et al., *"Cloud Busters": Reflections on the Right to Water in Clouds and a Search for International Law Rules*, 20 COLO. J. INT'L ENVTL. L. & POL'Y 321, 341–43 (2009); HUTCHINSON & HERRMANN, *supra* note 16, at 54; Kwa, *supra* note 15, at 162.

79. In the U.S. at least, commentators have observed how weather modification operations continued to expand despite a decrease in government funding for weather modification research, prompting a commentator to opine that "we have entered the 'dark ages' of weather modification where operational cloud seeding projects are, if anything, proliferating without a sound scientific research program supporting them." William R. Cotton, *Weather Modification by Cloud Seeding—A Status Report 1989–1997*, *in* ANTHROPOGENIC CLIMATE CHANGE 139, 153 (Hans von Storch & Götz Flöser eds. 1999); THEODORE STEINBERG, SLIDE MOUNTAIN, OR, THE FOLLY OF OWNING NATURE 107–09 (1995); *see also* Kwa, *supra* note 15, at 157 (discussing how federal funding for weather modification in the U.S. have substantially decreased since peaking in the 1960s); Virginia Simms, *Making the Rain: Cloud Seeding, the Imminent Freshwater Crisis, and International Law*, 44 INT'L L. 915, 928 (2010) (discussing the operations of private weather modification companies).

80. HUTCHINSON & HERRMANN, *supra* note 16, at 55. For a brief outline of the weather modification programs in selected countries, *see* Simms, *supra* note 79, at 922–28; *cf.* Kwa, *supra* note 15, at 157–64 (tracing the decline in state and public support for weather modification in the U.S. since the late 1960s and attributing the decline to—aside for the overstated scientific claims and the continued uncertainties of the technologies—the increased public awareness concerning the unintended effects to the overall climate that may results from human intervention).

81. *See, e.g.*, *Clients & Projects*, WEATHER MODIFICATION INC., http://weathermodification.com/projects.php (last visited Sept. 29, 2016) (listing clients in 19 countries: Antigua, Argentina, Australia, Burkina Faso, Canada, Greece, India, Indonesia, Jordon, Mali, Mexico, Morocco, Saudi Arabia, Senegal, Spain, Thailand, Turkey, U.A.E., and U.S). *See also* Weather Eng'g Corp. of Am. v. United States, 614 F.2d 281, 285 (1980) (discussing the commercial history of a Canadian weather modification company—Weather Engineering Corporation of Canada Ltd—which included engagement in Iran and Cyprus and inquiries by governments of India and the People's Republic of China in the 1960s and 1970s).

82. HUTCHINSON & HERRMANN, *supra* note 16, at 55; Cotton, *supra* note 79, at 158; *see* Bartlett, *supra* note 14, at 32 (noting that a one-to-ten cost benefit ratio is "not uncommon").

Political considerations are also undoubtedly a factor. Governments stand to benefit if they are perceived by their citizenry as actively attempting to alleviate some of the populace's most salient hardships, such as lack of adequate rain.[83]

B. Types of Weather Modification and Their Basic Mechanics

The most prominent type of weather modification—and the primary focus of this Article—is cloud seeding, a technology for inducing precipitation. Increased rainfall is highly beneficial to areas suffering from drought, as well as permanently arid areas. But alleviating dry conditions is by no means the only end to which the technology has been put. During the 2008 Beijing Olympics, for example, China conducted large-scale cloud-seeding operations to dissipate potential rain clouds before they could reach the vicinity of the main sporting venues.[84] Other cloud-seeding operations have attempted to reduce the strength of hurricanes[85] and suppress hail.[86]

Cloud-seeding involves dispersing a batch of certain chemicals (the "seeding agents") into a cloud in order to transform the cloud's structure into one more likely to release precipitation in the form of rain or snow. Although the exact science underpinning weather modification remains in flux, the practice is well-defined. In sum,[87] cold-based continental clouds are seeded with glaciogenic

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Increased rain may also increase the amount of hydropower generated and reduces the cost of electricity. *See* Larry R. Dozier, *Colorado River Augmentation*, 37 TRENDS 1, 14 (2006). For a general discussion on the various studies evaluating the economic efficacy of weather modification operations, *see* Conrad G. Keyes, Jr., *Societal, Environmental, and Economic Aspects of Precipitation Enhancement by Cloud Seeding*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION 9, 25–36 (Conrad G. Keyes Jr. et al. eds., 2006).

83. Simms, *supra* note 79, at 915–16 (noting the political considerations of shifting blame and strategic geo-political diplomacy that may explain Venezuelan cloud seeding modifications in 2009 to tackle severe drought); Cotton, *supra* note 79, at 158 ("Often the decision to apply cloud seeding technology in a particular country or state is a prescription of a political placebo or a decision that it is better to do something than to sit idly by and do nothing as reservoirs dry up and crops wither and die due to the absence of water.").

84. *Can Humans Control Weather*, US FED NEWS, May 15, 2009; Wang Xiuwei, *Rengong yingxiang tianqi quan jiexi* [*Analysis on Power of Weather Modification*], 5 HEBEI L. SCI. 34, 34 (2008).

85. GOUDIE, *supra* note 78, at 228; COTTON & PIELKE, *supra* note 14, at 63–65.

86. GOUDIE, *supra* note 78, at 227–28; Orville, *supra* note 15, at 443–44; Kwa, *supra* note 15, at 149–50; STEINBERG, *supra* note 79, at 112.

87. For detailed exposition of the underlying scientific theories, see generally COTTON & PIELKE, *supra* note 14, at 9–40; Robert Czys, Thomas P. DeFelice & Don A. Griffith, *The Scientific Basis*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION, *supra* note 82, at 61–76; Orville, *supra* note 15, at 436–38.

seeding agents, which triggers the formation of ice crystals from suspended supercooled liquid water by introducing impurities into the water; water can only remain in liquid form at sub-zero temperatures when impurities are absent (hence the term "supercooled"). Conversely, warm and maritime clouds are seeded with hygroscopic seeding agents that, attract surrounding water vapor to form cloud droplets and accelerate the formation of water droplets heavy enough to fall from the cloud as rain. The appropriate seeding agents and the optimal window for dispersal depend upon the structure of the targeted cloud.[88] Given the high altitudes at which cloud-seeding chemicals must be dispersed, effective seeding most often involves aerial disbursement, either via aircraft or through the use of such instruments as rockets or anti-aircraft guns. Certain clouds, such as orographic clouds (clouds formed by the forced lifting of air by topographic features such as mountains), can be seeded by generators placed on the ground.[89]

It is worth noting that weather modification can also be conducted on a much larger, "macro" level, with the primary aim of mitigating global climate changes. Known as geoengineering, the proposed operations range from the relatively mundane (fertilizing of the ocean to stimulate the growth of phytoplankton, which capture carbon dioxide through photosynthesis) to the grandiose (proposals to place a "sunshade" in space, to reduce the amount of solar radiation).[90] The legal issues raised by such macro activities are certainly fascinating.[91] But the regulation of geoengineering, as with all legal issues that are truly transnational in nature, runs up against a fundamental problem: the lack of established efficacious governing institutions.[92] Although conventional weather-modification may raise international environmental law issues in certain

88. For a relatively updated and detailed account on the various possible operational mechanisms for cloud-seeding, see Griffith, *supra* note 76, at 81–104; Orville, *supra* note 15, at 436–38.

89. Griffith, *supra* note 76, at 100–01; Orville, *supra* note 15, at 436–38.

90. Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 MICH. J. INT'L L. 309, 323, 329 (2013); Rafael Leal-Arcas & Andrew Filis-Yelaghotis, *Geoengineering a Future for Humankind: Some Technical and Ethical Considerations*, 2012 CARBON & CLIMATE L. REV. 128, 129 (2012).

91. For discussions on the legal issues that might arise from geoengineering, see Edward A. Parson & David W. Keith, *End the Deadlock on Governance of Geoengineering Research*, 339 SCIENCE 1278, 1278 (2013); Joshua B. Horton, Andrew Parker & David Keith, *Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities*, 22 N.Y.U. ENVTL. L.J. 225, 225–27 (2015); Leal-Arcas & Filis-Yelaghotis, *supra* note 90, at 134–35.

92. *See* Scott, *supra* note 90, at 329–39; Leal-Arcas & Filis-Yelaghotis, *supra* note 90, at 134–36; *cf.* Horton, Parker & Keith, *supra* note 91, at 265–71 (proposing a liability regime for solar geoengineering by drawing from existing international liability regimes).

circumstances,[93] its activities, as well as its benefits and costs, are generally confined within the jurisdiction of one nation (or, indeed, of one state or province). Thus, the examination of weather modification activities in this Article will leave aside geoengineering and the unique legal issues it raises.

C. Previous Scholarship on the Ownership of Atmospheric Moisture

Weather modification offers great promise: generating weather conditions highly beneficial to selected human activities and human subsistence in certain climates. Even so, it is not without its controversies. On top of the operational risks involved in weather-modification activities[94] and the possibly harmful environmental effects of certain seeding chemicals,[95] weather modification raises a number of important legal concerns: the diversion of rainwater to the detriment of nearby land[96] or competing conceptions of the optimal weather to induce.[97] Unsurprisingly, such externality and redistribution problems have led to the standard calls for regulatory intervention.[98] But the property rights to atmospheric moisture have also been a primary focus both of the literature and of litigation.

The typical scale of weather modifications covers large tracts of land and, in some instances, large swaths of the population. The nature of property rights and personal autonomy mean that consent—of landowners and of other individuals affected by weather modifications—is always a potential issue, even when there is no

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93. The issue is most salient for large scale weather modification activities near the borders of neighboring nations. Simms, *supra* note 79, at 930–35; Majzoub et al., *supra* note 78, at 355–59.

94. *See, e.g.*, Yang Hua & Xiao Baopin, Lun rengong yingxiang tianqi de falv jiuji ji fayuan de zuoyong—yi fayuan canyu shehui guanli chuangxin wei shijiao [*On the Legal Remedies of Weather Modification and the Role of the Court: A perspective of Court's Participation in Social Innovation of Management*], 2012 J. JIANGHAN U. (SOC. SCI. EDITION) 48, 48 (2012); Simms, *supra* note 79, at 921.

95. Simms, *supra* note 79, at 921; *see* Bartlett, *supra* note 14, at 33–34 (acknowledging the concern but arguing that the minute amount of chemical agents used meant that the health effect is likely to be negligible).

96. *See* Davis, *supra* note 14, at 35; HUTCHINSON & HERRMANN, *supra* note 16, at 49; Cotton, *supra* note 79, at 158.

97. *See* Majzoub et al., *supra* note 78, at 340; Thomas P. DeFelice & Conrad G. Keyes, Jr., *Executive Summary*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION, *supra* note 82, at 1–2; Kwa, *supra* note 15, at 149–50.

98. *See, e.g.*, Lance D. Wood, *The Status of Weather Modification Activities Under United States and International Law*, 10 NAT. RESOURCES L. 367, 389–91 (1977); Hene, *supra* note 6, at 287–88; Vaughn C. Ball, *Shaping the Law of Weather Control*, 58 YALE L.J. 213, 237–44 (1949).

prospect of harm.[99] The issue of ownership has always featured prominently in legal discussions of weather modification, even in the earliest law review articles.[100] This issue continues to loom large.[101]

Despite the ink spilled on the issue, no consensus has emerged on what form of ownership is most appropriate for atmospheric moisture. A variety of possible property rights arrangements have been proposed and discussed. Broadly speaking, the proposals fall into one of two categories. First, that ownership be premised on ownership of the underlying land, either through the *ad coelum* rule (the landowner owns all natural resources above and underneath her land),[102] the rule of capture (the landowner retains ownership of the natural resources that are captured or utilized over her land),[103] or the natural-right doctrine (the landowner is to be protected from adverse interference with the natural weather conditions over her land).[104]

The second category of proposals rejects private ownership, either because of the intangible nature of atmospheric moisture or because of concerns over redistribution. In addition to proposals for public or state ownership,[105] this category includes proposals to treat atmospheric moisture as *res communes,* whereby atmospheric

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99. *See* HUTCHINSON & HERRMANN, *supra* note 16, at 49.

100. *See, e.g.*, Stark, *supra* note 6, at 703–04; *Who Owns the Clouds?*, *supra* note 5; *see also* Howard J. Taubenfeld, *Weather Modification and Control: Some International Legal Implications*, 55 CAL. L. REV. 493, 496 (1967) ("There will be no discussion, however, of theories of ownership, liability and the like within the domestic law context . . . [since] these problems have been explored at length in many existing studies.").

101. *See, e.g.*, MA Rabie & MM Loubser, *Legal Aspects of Weather Modification*, 23 COMP. & INT'L L.J. S. AFR. 177, 195–97 (1990) (writing that "[i]n order to discuss rights with regard to precipitation, it is necessary first to consider certain aspects of property law" before proceeding to duly analyze the issues such as the "ownership of air" and the "ownership of clouds."). The first legal issue identified by Virginia Simms in her examination of "the Law, Liability, and Potential Dangers of Weather Modification" is "Cloud and Water Ownership under Property Rights Law." Simms, *supra* note 79, at 928–30. Similarly, Tarek Majzoub et al. framed the first of the three issues they examined as "who has the [property] right to water in clouds?" Majzoub et al., *supra* note 78, at 322.

102. *See* Simms, *supra* note 79, at 929; Rabie & Loubser, *supra* note 101, at 196; *Who Owns the Clouds?*, *supra* note 5, at 48–49. For general discussion about the ad coleum rule, see Rule, *supra* note 3, at 806; K.K. DuVivier, *Animal, Vegetable, Mineral—Wind? The Severed Wind Power Rights Conundrum*, 49 WASHBURN L.J. 69, 76 (2009).

103. Simms, *supra* note 79, at 929; Majzoub et al., *supra* note 78, at 328–29; *Who Owns the Clouds?*, *supra* note 5, at 49–51. *See* DAINTITH, *supra* note 20, at 3–50 (discussing the background and juridical recognition of the rule of capture in petroleum extraction); *see also* Melissa H. Loja, *Is the Rule of Capture Countenanced in the South China Sea? The Policy and Practice of China, the Philippines and Vietnam*, 32 J. ENERGY & NAT. RESOURCES L. 483, 486–90 (2014) (discussing the rule of capture in the international law context).

104. *Who Owns the Clouds?*, *supra* note 5, at 54–58.

105. Majzoub et al., *supra* note 78, at 331–32 (in the context of precipitation); *Who Owns the Clouds?*, *supra* note 5, at 57–60.

moisture is common property of the public subject to the right of enjoyment by the public,[106] or *res nullius,* whereby the atmospheric moisture is owned by no one.[107]

III. WEATHER-MODIFICATION REGULATIONS AND OWNERSHIP AMONG THE 50 STATES

This Part examines how the fifty states regulate the use of atmospheric moisture, and focuses on how the arrangements of property rights to atmospheric moisture interact with the diverse array of regulatory regimes that states have adopted.

A. Overview of Diverse Regulatory Regimes

1. Federal Law (or the Absence Thereof)

There are no comprehensive federal laws or regulations governing weather modification. Putting aside congressional acts that created, funded, or directed regulatory agencies to conduct research on weather-modification activities,[108] the sole federal legislation imposing actual regulatory controls on weather-modification activities is the Weather Modification Reporting Act of 1972.[109]

As the Act's title indicates, this short and straightforward piece of legislation imposes an obligation to report weather-modification activities. In the regulations implementing the statute, a "weather

106. Simms, *supra* note 79, at 929–30; Majzoub et al., *supra* note 78, at 327, 361; Rabie & Loubser, *supra* note 101, at 196–97. For general discussion, see Carol M. Rose, *Romans, Roads, and Romantic Creators: Traditions of Public Property in the Information Age*, 66 L. & CONTEMP. PROBS. 89, 93–94 (2003); ANDREW BORKOWSKI, TEXTBOOK ON ROMAN LAW 143 (Blackstone Press 1994).

107. Majzoub et al., *supra* note 78, at 329–30.

108. *See, e.g.*, National Weather Modification Policy Act of 1976, Pub. L. No. 94-490, 90 Stat. 2359 (1976) (directing the Secretary of Commence to research and report to Congress on the prospects of developing and implementing weather-modification regulations at the national level); Weather Modification Evaluation Act, Pub. L. 256, 67 Stat. 559 (1953) (creating the Advisory Committee on Weather Control to evaluate private and public experiments on weather modification). For discussions of these regulatory developments and their implications for the trajectory of weather-modification research, *see* Kwa, *supra* note 15, at 140; Wood, *supra* note 98, at 374–76.

109. Weather Modification Reporting Act of 1972, 15 U.S.C. §§ 330–330e (1971). For a discussion of the federal government's decision not to comprehensively regulate weather-modification activities, see Ray Jay Davis, *Future Legal Regulation of Weather Modification*, 114 J. IRRIGATION & DRAINAGE ENGINEERING 705, 706 (1988).

modification activity" is defined as "any activity performed with the intention of producing artificial changes in composition, behavior, or dynamics of the atmosphere."[110] The information to be reported includes the particular sponsor and operator, the timing and location of the operation, and descriptions of the weather-modification techniques used and the equipment employed.[111] The reported information, save confidential information or information that is otherwise prohibited from disclosure, shall be made publicly available.[112] The reporting entity must also keep and maintain more detailed records of its weather-modification activities.[113] Violations of the reporting obligation are subject to a modest fine of up to $10,000.[114]

No other federal controls exist in either the Act or other federal laws and regulations. This lack of preemptive federal regulations gives states a free opportunity to design their own weather-modification regulatory regimes.[115] The remainder of this Part examines how states have exercised this freedom.

2. Has, Had, Never

The states have adopted a wide variety of weather modification regulatory regimes. Most, however, have declined to legislate in this realm. The most common state regulatory regime remains none at all. At the beginning of 2015, eighteen states had passed legislation concerning the conduct of weather-modification activities: Arizona, California, Colorado, Florida, Kansas, Louisiana, Montana, Nevada,

110. Maintaining Records and Submitting Reports on Weather Modification Activities, 15 C.F.R. § 908.1(c) (1976). All such activities must be reported, excluding those activities that "can reasonably be expected to not modify the weather outside of the area of operation." *Id.* at § 908.3(c). Another interesting exception is one for "religious activities or other ceremonies, rites and rituals intended to modify the weather." *Id.* Oklahoma is the only state that has a similar religious exception in its regulatory scheme on weather-modification activities. *See* OKLA. STAT. Tit. 82 § 1087.1.8.4 (2014).

111. Maintaining Records and Submitting Reports on Weather Modification Activities, 15 C.F.R. § 908.4–908.6 (1976).

112. 15 U.S.C. § 330b (1971); 15 C.F.R. §908.12 (1976).

113. 15 C.F.R. §§ 908.8 & 908.11 (1976).

114. 15 U.S.C. §§ 330a & 330d (1971).

115. For critical discussion of the preemption doctrine in the U.S., see Michael P. Moreland, *Preemption as Inverse Negligence Per Se*, 88 NOTRE DAME L. REV. 1249, 1253–58 (2013); Jamelle C. Sharpe, *Toward (A) Faithful Agency in the Supreme Courts Preemption Jurisprudence*, 18 GEO. MASON L. REV. 367, 380–405 (2011); *c.f.*, Wood, *supra* note 98, at 390–91 (arguing for some minimum federal oversight over weather modifications given the inter-state ramifications of large-scale weather modification activities).

North Dakota, New Mexico, Oklahoma, Oregon, Pennsylvania, Texas, Utah, Washington, Wisconsin, and Wyoming.[116]

Another eight states, Illinois,[117] Indiana,[118] Iowa,[119] Michigan,[120] Minnesota,[121] Nebraska,[122] South Dakota,[123] and West Virginia,[124] formerly had laws concerning weather modification but have repealed them. The actual number of such states, however, is likely higher, as the legislative amendments affecting the repeal may have completely removed any reference to the regime from the statute books.[125] While most of the eight states repealed their weather modification legislations in the 1990s, South Dakota's (in 2012) and Oklahoma's (in May 2015) repealed theirs only recently.[126]

3. License/Permit Requirement

Among the eighteen states that currently have regulatory controls over weather modification activities, approximately half have a single-tier licence/permit requirement for weather-modification activities. Kansas,[127] Montana,[128] Nevada,[129] North Dakota,[130]

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116. In addition, Maryland has statutory authorization for local governments in selected counties to enact and implement regulations relating to weather modification activities. MD. CODE § 13-701 (2013).

117. 5 IL. COMP. STAT. ANN. 80/4.6 (repealed 1992).

118. IND. CODE § 13-1-1.5-1–5-17 (repealed 1991).

119. IOWA CODE ANN. §§ 361.1–361.7 (repealed 1994).

120. MICH. COMP. LAWS ANN. §§ 295.101–295.132 (repealed 2000).

121. MINN. STAT. ANN. §§ 42.01–42.14 (enacted 1977, repealed 1999).

122. NEB. REV. STAT. § 2-401 (repealed 1996).

123. S.D. CODIFIED LAWS § 46-3A-1–3 (repealed 2012). South Dakota's eventual repeal of the statute is worth noting given that it is the first state to have had a state-sponsored weather modification program. In 1972, at its height, the program covered sixty percent of the land area of the state, and a majority of the population used to be very supportive of the weather modification in light of potential benefits to the state's agriculture-based economy. Keyes, *supra* note 82, at 12.

124. W. VA. ANN. CODE § 29-2B-1–29-2B-15 (repealed 1995).

125. One possible mechanism is through sunset provisions that automatically renders the law void if the legislature do not actively passed a reauthorization. Davis, *supra* note 109, at 706.

126. H.B. 1420, OPEN STATES, http://openstates.org/ok/bills/2015-2016/HB1420/ (last visited Sept. 29, 2016). The bill was introduced with the barest of explanation concerning rationale (i.e., "antiquated law" that has not been used) and passed with more than a ninety percent majority without any substantive debate. *Bill Info For HB 1420*, OKLA. STATE LEGISLATURE, http://oklegislature.gov/BillInfo.aspx?Bill=HB1420&Session=1500 (last visited Sept. 29, 2016). According to the spokesperson of the regulatory authority, weather modification operations were carried out in the 1970s and 1980s, but there had been no operations since 1988 until an application in early 2015. Brian Brus, *Making it Rain: Lawton Pursues Cloud Seeding to Fight Drought*, THE JOURNAL RECORD (Oklahoma City, OK), (Mar. 27, 2015), http://journalrecord.com/2015/03/27/making-it-rain-lawton-wants-to-try-cloud-seeding-to-fight-drought-general-news/.

127. KAN. STAT. ANN. § 82a-1406(a) (1974).

Oklahoma,[131] Texas,[132] Washington,[133] and Wisconsin[134] employ a dual-tier regulatory scheme, which requires would-be operators first to secure a license and then to apply for a permit that will authorize specific operations.[135] California is a unique case; though it repealed its license- and permit-requirement provisions in 1984, its pre-operation public-notice[136] and record-keeping requirements[137] remain in place.

Substantively, though, this structural difference between regulatory regimes is largely immaterial. Regardless of whether a state has single- or double-tier licensing, it almost invariably requires[138] that would-be weather-modifiers have "professional" competence or qualifications in the field. There is a significant divergence among jurisdictions, however, in what constitutes the requisite professional qualifications. The majority of states define professionalism vaguely or tautologically; the relevant laws call for "skill," "competence," or "qualification" in "meteorology" and/or the intended weather-modification activities. Many states cede responsibility for promulgation of more specific rules to the regulatory agency.[139] Wisconsin,[140] Kansas,[141] and New Mexico[142] are the only states with more specific

128. MONT. CODE ANN. § 85-3-201 (1967).

129. NEV. REV. STAT. § 544.120 (1961).

130. N.D. CENT. CODE §§ 61-04.1-11, -14 & -16 (1981).

131. OKLA. STAT. tit. 82 § 1087.7 (2014).

132. TEX. AGRIC. CODE § 301.101 (2003).

133. WASH. STAT. §§ 43.37.100 & .110 (1973).

134. WIS. STAT. § 93.35(2) (1977).

135. For general discussion about the structure of regulation relating to weather modification activities, *see* George W. Bomar, *Legal Aspects of Weather Modification Operations*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION, *supra* note 82, at 43, 44–50.

136. CAL. WATER CODE § 411 (Deering 1984).

137. *Id.* at § 420.

138. Colorado is an interesting exception: it requires only financial responsibility, eschewing any requirement of professional expertise. This situation arose after it removed its licensing requirement, which previously set forth the professional expertise requirement in the context of a dual-layer regulatory scheme. *See* COLO. REV. STAT. §§ 36-20-110–112 (1972).

139. *See, e.g.*, FLA. STAT. ANN. § 403.331(a) (LexisNexis 2014); LA. STAT. ANN. § 37:2207 (1956); MONT. CODE ANN. § 85-3-203 (1967); NEV. REV. STAT. § 544.140(1) (1961); N.D. CENT. CODE § 61-04.1-14.2 (1981); OKLA. STAT. tit. 82 § 1087.1.9.A (2014); OR. REV. STAT. § 558.060 (1955); TEX. AGRIC. CODE § 301.103(a)(2) (2003); UTAH STAT. § 73-15-6 (1973); WASH. STAT. § 43.37.100(1) (1973); WYO. STAT. ANN. § 9-1-907(b) (1951).

140. WIS. STAT. § 93.35(4)(a) (1977) ("[C]onsistent with qualifications recognized by national or international professional and scientific associations concerned with weather modification and meteorology.").

141. KAN. STAT. ANN. § 82a-1407 (1974) ("[A]t least eight years of professional experience in weather modification field research or activities and has served for at least three years as a project director of weather modification activities" or "a baccalaureate degree from a recognized institution of higher learning in meteorology, engineering, mathematics or the physical sciences and (A) Has had at least three seasons of experience in weather modification field research or activities; (B) has satisfactorily completed the equivalent of at least 25

legislative benchmarks. At the other extreme are Arizona[143] and Pennsylvania,[144] which require would-be operators to provide information related to their professional qualifications during the application process but nonetheless do not expressly require that applicants possess any particular level of expertise in order to receive a permit/license.

The capacity to meet financial liabilities that may arise from the approved weather-modification activities is also a typical, but not universal, condition for receiving a license. The main differences are found in the breadth of liability that an operator must undertake. The relevant provision may be narrowly worded, to primarily cover accidents during the operation (e.g., "damages for liability on account of accidents arising out of the weather modification operations"),[145] or more broadly, to cover not only accidents but also adverse weather effects (e.g., "obligations reasonably likely to be attached to or result from the proposed weather modification operation").[146] Nevada's statute is uniquely unambiguous; it expressly excludes the latter type of liability.[147]

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semester hours of meteorological studies and has had at least two seasons of practical experience in weather modification field research or activities; or (C) is certified by the weather modification association.").

142. N.M. Stat. Ann. § 75-3-7 (LexisNexis 1978) ("[S]kills and experience reasonably necessary to the accomplishment of weather control without actionable injury to property or person."). This provision is intriguing in that the ostensibly specific criteria of "necessary" to avoid "actionable injury to property or person" is actually highly ambiguous given the paucity of court judgments on civil liabilities associated with weather modification activities in the U.S. in general and starkly zero in New Mexico.

143. ARIZ. REV. STAT. § 45-1603.A.3 (LexisNexis 1987).

144. 3 PA. STAT. ANN. § 1106(b)(2) (LexisNexis 1968).

145. FLA. STAT. ANN. § 403.321 (LexisNexis 2014); KAN. STAT. ANN. § 82a-1411(a)(4) (1974). Similar statutory language can also be found in OR. REV. STAT. § 558.050 (1955) as well as UTAH STAT. § 73-15-6 (1973)

146. COLO. REV. STAT. § 36-20-112 (1972). Similar statutory language can also be found in MONT. CODE ANN. § 85-3-211 (1967); N.D. CENT. CODE §§ 61-04.1-16.1(a) & -19 (1981); N.M. Stat. Ann. § 75-3-7 (LexisNexis 1978); 3 PA. STAT. ANN. § 1106(b)(5) (LexisNexis 1968); OKLA. STAT. tit. 82 § 1087.14 (2014); TEX. AGRIC. CODE § 301.114 (2003); WASH. STAT. § 43.37.150 (1973); WIS. STAT. § 93.35(7) (1977).

147. NEV. REV. STAT. § 544.190 (1961) ("Proof of financial responsibility may be furnished by an applicant by the applicant's showing, to the satisfaction of the Director, the applicant's ability to respond in damages for liability which might reasonably be attached to or result from weather modification and control activities in connection with the operation for which the applicant seeks a permit; but the applicant need not show ability to respond in damages for liability resulting from precipitation caused by weather modification experiments.").

4. Information Management

Echoing the sole federal regulatory obligation—that is, reporting—state legislation typically imposes a reporting obligation upon permitees/licensees. With the exception of Louisiana, which has no explicit reporting requirement,[148] the main variance among the states is whether the reports are subject to public disclosure. The majority (ten out of eighteen states) require public disclosure of the reports.[149] The reporting requirements of the states of Arizona,[150] California,[151] Kansas,[152] New Mexico,[153] Utah,[154] and Wyoming[155] do not explicitly contain the availability of a public inspection.

Most states' reporting requirements are unremarkable, as they are highly similar to the federal requirement.[156] One notable exception is Wisconsin; it requires operators to report, among other things, "the times when there was modifiable weather but the permittee did not operate and the reasons for not operating."[157]

In addition to the data collection enabled by the reporting obligation, pre-operation public-notice requirements seek to facilitate anticipatory measures in view of the proposed weather modifications. Public notice is a common requirement; most states (thirteen out of eighteen) have such provisions on the books.[158] Of those

148. Instead, the statute imposes the duty to collect and evaluate information on the regulator. LA. STAT. ANN. § 37:2208 (1956) ("The commissioner shall evaluate each weather modification operation and publish the results of such evaluation in an annual report.").

149. COLO. REV. STAT. § 36-20-117 (1972); FLA. STAT. ANN. § 403.381 (LexisNexis 2014); MONT. CODE ANN. §§ 85-3-301–303 (1967); NEV. REV. STAT. § 544.210 (1961); OKLA. STAT. tit. 82 § 1087.16 (2014); OR. REV. STAT. § 558.110 (1955); 3 PA. STAT. ANN. § 1110 (LexisNexis 1968); TEX. AGRIC. CODE § 301.117 (2003); WASH. STAT. § 43.37.170 (1973); WIS. STAT. § 93.35(12) (1977).

150. ARIZ. REV. STAT. § 45-1604 (LexisNexis 1987).

151. CAL. WATER CODE § 420 (Deering 1984).

152. KAN. STAT. ANN. § 82a-1417 (1974).

153. N.M. STAT. ANN. § 75-3-9 (LexisNexis 1978).

154. UTAH STAT. § 73-15-5 (1973).

155. WYO. STAT. ANN. § 9-1-907(c) (1951).

156. There are three possible reasons for such seemingly redundant reporting requirements. First, some state statutes were enacted prior to the federal regulation. Second, states may want to preserve the flexibility in determining the information that should be required. Third, a state-level reporting requirement facilitates states' access to information, especially since state government (unlike other departments of the Federal government) do not have automatic access to any reported information that has been designated confidential. Maintaining Records and Submitting Reports on Weather Modification Activities, 15 C.F.R. § 908.12(a) (1976).

157. WIS. STAT. § 93.53(12)(b) (1977).

158. CAL. WATER CODE § 410 (Deering 1984); COLO. REV. STAT. § 36-20-112 (1972); FLA. STAT. ANN. § 403.361 (LexisNexis 2014); KAN. STAT. ANN. § 82a-1411(a)(6) (1974); MONT. CODE ANN. § 85-3-210 (1967); N.D. CENT. CODE § 61-04.1-17 (1981); NEV. REV. STAT. § 544.180 (1961); OKLA. STAT. tit. 82 § 1087.13 (2014); 3 PA. STAT. ANN. § 1108 (LexisNexis

thirteen, eight further provide for public hearings in conjunction with the issuance of a particular permit/license, although the right to a public hearing ranges from discretionary (i.e. providing that officials may hold a hearing in response to post-notice objections by the public)[159] to mandatory (i.e., requiring officials to hold a hearing regardless of whether any member of the public has actually raised an objection).[160]

5. Regulatory Fees and Other Direct Financial Burdens

Typically, private entities engage in weather modification with the goal of harnessing atmospheric moisture for their own benefit. Accordingly, the public may object to weather modification on the ground that it stands to redistribute a natural resource that was previously available to all (if haphazardly so).[161] In this respect, it is important to note how different states address such redistribution when imposing fees and costs on weather-modifiers operators.

Most of the overt fees and costs states impose are the license/permit fees discussed above. Many states have very modest fees, with some even as low as $100.[162] Although certain fees were established decades ago and have remained unchanged, $100 remains relatively modest—less than $1000, when adjusted for inflation.[163] Still, the flat-fee nature of these fees favors large-scale commercial weather modification operations, whereas the structure subjects

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1968); OR. REV. STAT. § 558.090 (1955); TEX. AGRIC. CODE § 301.110 (2003); WIS. STAT. § 93.35(6)(c) (1977); WASH. STAT. § 43.37.140 (1973).

159. N.D. CENT. CODE § 61-04.1-17 (1981); TEX. AGRIC. CODE § 301.107(b) (2003); *see also* KAN. STAT. ANN. § 82a-1411(b) (1974) (stipulating that the regulatory authority "may hold a public hearing" without stating the circumstances where such public hearing is warranted or desired).

160. COLO. REV. STAT. § 36-20-112(2) (1972); MONT. CODE ANN. § 85-3-202(1) (1967); OR. REV. STAT. § 558.055 (1955); WASH. STAT. § 43.37.110(6) (1973); WIS. STAT. § 93.53(6)(c) (1977).

161. STEINBERG, *supra* note 79, at 115–16.

162. *E.g.*, ARIZ. REV. STAT. § 45-1603 (LexisNexis 1987) ($100 per license); FLA. STAT. ANN. §§ 403.311(2) & 331(3) (LexisNexis 2014) ($1000 for application, and $50 for annual renewal); KAN. STAT. ANN. § 82a-1408 (1974) ($100 annual license fee & $100 for permit); LA. STAT. ANN. § 37:2203 (1956) ($100 per license); N.D. CENT. CODE §§ 61-04.1-14.1 & -16.1 (1981) ($50 annual license fee; $25 for each operation permit); N.M. Stat. Ann. § 75-3-6 (LexisNexis 1978) ($100 annual license fee); OKLA. STAT. tit. 82 § 1087.9.B (2014) ($100 annual license fee); OR. REV. STAT. § 558.010 (1955) ($100 license fee); 3 PA. STAT. ANN. § 1106 (LexisNexis 1968) ($100 annual license fee); WYO. STAT. ANN. § 9-1-907(b) (1951) ($100 for each permit).

163. *CPI Inflation Calculator*, BUREAU OF LABOR STATISTICS, http://www.bls.gov/data/inflation_calculator.htm (last visited Sept. 29, 2016).

small and medium enterprises to disproportionately heavy financial burdens.

Nevada, Montana, Washington, and Wisconsin stand out for imposing fees that more closely track the scale of the weather-modification activities. Nevada[164] and Washington[165] set permit fees at one and one-half percent of the estimated cost of operation, and Montana sets them at one percent.[166] Wisconsin, though also charging one percent, assesses that charge on the value of the contract, which tends to be higher than the actual cost of the operations.[167]

Another dimension of the redistributive effect is the manner in which states allocate the costs of running the regulatory regime itself. Although the collected license/permit fees are often earmarked for operating the regulatory regime,[168] a flat modest license/permit fee is unlikely to cover a state's actual costs of regulation.[169] In this respect, it is noteworthy that Colorado, although it sets the base permit fee at $100, does mandate upward adjustments for commercial weather-modification projects, to cover the expenses of the approval process (e.g., application review, public hearing, and post-application monitoring).[170] Montana's similar cost-recovery provision is more aggressive still, given that the state already imposes substantial permit fees.[171]

Beyond direct cost recovery, there are subtler means by which states may lessen their regulatory costs. One example comes in the form of the public-notice requirement, which exists in thirteen states. Montana,[172] North Dakota,[173] and Wisconsin[174] place notice obligations on the regulatory authority, but the remaining states

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164. NEV. REV. STAT. § 544.200 (1961). This is in addition to the $100 license fee. *See* NEV. REV. STAT. § 544.140 (1961).

165. WASH. STAT. § 43.37.160 (1973). This is in addition to the $100 license fee. *See* WASH. STAT. § 43.37.100(2) (1973).

166. MONT. CODE ANN. § 85-3-212 (1967). This is in addition to the $100 license fee. *See* MONT. CODE ANN. § 85-3-205 (1967).

167. WIS. STAT. § 93.35(6)(g) (1977) (stating that if there is no contract, the estimated cost of the weather modification operations will be used). This is in addition to the $100 license fee. *See* WIS. STAT. § 93.35(4) (1977).

168. *See, e.g.*, MONT. CODE ANN. § 85-3-213 (1967); OKLA. STAT. tit. 82 § 1087.6.B. (2014). Some states deposit the permits fees to the general fund. *See, e.g.*, N.D. CENT. CODE § 61-04.1-14 (1981); TEX. AGRIC. CODE § 301.060 (2003).

169. *See Davis*, *supra* note 109, at 707 (noting that "in at least one state lack of funding [has] curtailed regulatory activities").

170. COLO. REV. STAT. § 36-20-113 (1972).

171. This includes the costs of conducting the public meeting, preparing the environmental impact statement, publication of notice of intention: MONT. CODE ANN. § 85-3-202(1) & -210(2) (1967).

172. MONT. CODE ANN. § 85-3-210 (1967).

173. N.D. CENT. CODE § 61-04.1-17 (1981).

174. WIS. STAT. § 93.35(6)(c) (1977).

put those obligations on the applicants. Applicants must submit proof of a conforming newspaper publication before their permit can be approved.[175] This cost-shifting has clear implications. Montana has an independent provision requiring applicants to reimburse the state for the costs of regulatory-approval,[176] but applicants in North Dakota and Wisconsin are exempted from otherwise substantial newspaper-advertising fees. Placing the notification burden on the regulatory authority cannot be explained by cost advantages (e.g., the state creating a centralized official notification avenue) because, in all three states, the regulatory authority is required by statute to use conventional media outlets (i.e., newspapers) to satisfy the public-notification obligations.[177]

6. Legal Liability

Sometimes, the enacted legislation seeks to clarify the legal liability that may arise from conducting weather modification activities. A majority of states have provisions that expressly preclude any state liability for damages for weather-modification activities approved in conformity with the state's regulatory scheme.[178] In any event, this disclaimer is likely unnecessary, as states by default usually enjoy considerable immunity from civil liability relating to its regulatory regimes.[179]

Considerably more interesting is how state regulatory regimes address civil liability of non-state actors. One approach, which has been adopted by Kansas,[180] Oklahoma,[181] Nevada,[182] Washington,[183]

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175. CAL. WATER CODE § 410 (Deering 1984); COLO. REV. STAT. § 36-20-112 (1972); FLA. STAT. ANN. § 403.361 (LexisNexis 2014); KAN. STAT. ANN. § 82a-1411(a)(6) (1974); NEV. REV. STAT. § 544.180 (1961); OKLA. STAT. tit. 82 § 1087.13 (2014); 3 PA. STAT. ANN. § 1108 (LexisNexis 1968); OR. REV. STAT. § 558.090 (1955); TEX. AGRIC. CODE § 301.110 (2003); WASH. STAT. § 43.37.140 (1973).

176. MONT. CODE ANN. §§ 85-3-202(1), 85-3-210(2) (1967).

177. MONT. CODE ANN. § 85-3-210 (1967); N.D. CENT. CODE § 61-04.1-17 (1981); WIS. STAT. § 93.35(6)(c) (1977).

178. COLO. REV. STAT. § 36-20-122 (1972); KAN. STAT. ANN. § 82a-1420 (1974); MONT. CODE ANN. § 85-3-104 (1967); NEV. REV. STAT. § 544.230 (1961); N.D. CENT. CODE § 61-04.1-36 (1981); OKLA. STAT. tit. 82 § 1087.19 (2014); TEX. AGRIC. CODE § 301.301 (2003); WASH. STAT. § 43.37.190 (1973); WIS. STAT. § 93.35(13) (1977); WYO. STAT. ANN. § 9-1-909 (1951).

179. Ken Lerner, *Governmental Negligence Liability Exposure in Disaster Management*, 23 URB. LAW. 333, 339–40 (1991) ("The discretionary function test was adopted by the federal government in the Federal Tort Claims Act, and some version of discretionary immunity is recognized by nearly every state."); Steven J. Schwartz, *Damage Actions as a Strategy for Enhancing the Quality of Care of Persons with Mental Disabilities*, 17 N.Y.U. REV. L. & SOC. CHANGE 651, 663 n.49 (1990).

180. KAN. STAT. ANN. § 82a-1422 (1974) (explaining that regulatory compliance shall provide no defense in actions for damages or injunctive relief).

and Wyoming,[184] is to declare that the regulatory scheme had no effect on the contract, tort, or other legal liabilities of private entities, which essentially leaves it entirely to the courts to determine the appropriate resolution of disputes.

Another approach is to alter or clarify the civil liability of private entities, particularly tort liability. There is no dominant pattern of such adjustments. Some states seek to limit the liability of weather modifiers. For example, Utah clarifies that approved operations do not lead to a presumption concerning trespass and nuisance.[185] Other states adopt a form of give-and-take. Texas, for example, removes ultra-hazardous-activity liability (i.e., liability without fault), but otherwise purports not to change the terms of legal relationships, and goes so far as to specify that the bare fact of regulatory compliance shall be inadmissible.[186] North Dakota similarly specifies that weather modification activities shall not be subject to strict liability (i.e., liability without fault) and trespass liability (for substances disseminated into the atmosphere in accordance with the permit), while at the same time leaving negligence and intentional-tort liability intact, again to the point of rendering inadmissible the fact that the weather modification activities are conducted in compliance with a valid license and permit.[187] Wisconsin's provision resembles North Dakota's, while adding that failure to comply with the license and permit requirement constitutes negligence.[188] This is Colorado's approach as well; it removes trespass and nuisance liability (both public and private), but provides that any violation of the permit requirement constitutes negligence per se[189] and that compliance with a permit is inadmissible as a defense in actions for damages or injunctive relief.[190]

Pennsylvania takes an interesting and surprisingly direct approach to civil liability arising from weather effects: compensation is to be determined administratively[191] by the Weather Modification

181. OKLA. STAT. tit. 82 § 1087.19 (2014).
182. NEV. REV. STAT. § 544.200 (1961).
183. WASH. STAT. § 43.37.190 (1973).
184. WYO. STAT. ANN. § 9-1-909 (1951).
185. UTAH STAT. § 73-15-7 (1973).
186. TEX. AGRIC. CODE § 301.302 (2003).
187. N.D. CENT. CODE § 61-04.1-37 (1981).
188. WIS. STAT. § 93.35(14) (1977).
189. COLO. REV. STAT. § 36-20-123 (1972).
190. *Id.* at § 36-20-124.
191. 3 PA. STAT. ANN. § 1114 (LexisNexis 1968) ("Any licensee who causes a drought as determined by the board shall compensate farmers for damages. Any licensee who by causing heavy downpours or storms which cause damage to lands as determined by the board shall compensate farmers and property owners for such damages.").

Board.[192] Beyond providing an alternative avenue for this difficult factual issue, Pennsylvania courts have used this provision to foreclose demands for injunctive relief, on the grounds that the provision provides "adequate relief at law."[193] It would be illuminating to examine how this administrative determination has operated in practice, particularly as a possible alternative to judicial adjudication.[194] In particular, the existence of at least one scientific expert (the Dean of the College of Earth Sciences at Pennsylvania State University, alongside regulators of relevant agencies, is expressly designated as a member of the seven-member board)[195] might have a positive influence in properly assessing the scientific evidence and expert testimonies in determining causation.[196] Unfortunately, however, there have been no newspaper reports of any disputes being adjudicated by that administrative organ.[197] Indeed, there is not even a webpage within the Pennsylvania state government website that displays the composition and activities of the Weather Modification Board.[198]

7. Diversity in the Face of Uncertainty

Before diving into the core issue of the relationship between property rights and the regulatory regime, it is worth assessing the significant differences between states' weather-modification regulatory regimes as those differences emerge from the above survey. In terms of structure, substantive rules, and even the basic decision of

192. 3 PA. STAT. ANN. § 1103 (LexisNexis 1968).

193. Pennsylvania Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 44 Pa. D. & C.2d 749 (1968).

194. *See* Thomas O. McGarity & Sidney A. Shapiro, *Regulatory Science in Rulemaking and Tort: Unifying the Weight of the Evidence Approach*, 3 WAKE FOREST J.L. & POL'Y 65, 90–102 (2013) (discussing how the weight of evidence approach adopted by regulatory agencies, which gives different evidentiary weights to scientific studies in accordance to their reliability, is superior to the corpuscular approach, which completely rejects scientific studies that have reliability issues. Courts typically use the corpuscular approach in tort litigations in terms of dealing with scientific uncertainty).

195. 3 PA. STAT. ANN. § 1103 (LexisNexis 1968).

196. Andrei Shleifer, *Efficient Regulation*, *in* REGULATION VERSUS LITIGATION: PERSPECTIVES FROM ECONOMICS AND LAW 27, 38 (Daniel P. Kessler ed., 2011); Ann Bloom, *Zen and the Art of Tort Litigation*, 44 LOY. L.A. L. REV. 11, 23–24 (2010). For general discussion about the extent and implication of Daubert v. Merrell Dow Pharmaceuticals, 509 U.S. 579 (1993), the leading U.S. Supreme case on expert testimony, see ALEX STEIN, FOUNDATIONS OF EVIDENCE LAW 196–97 (2005); Peter W. Huber, *Junk Science in the Courtroom: The Impact on Innovation*, *in* PRODUCT LIABILITY AND INNOVATION: MANAGING RISK IN AN UNCERTAIN ENVIRONMENT 138, 141–46 (Janet R. Hunziker & Trevor O. Jones eds., 1994).

197. Search, Feb. 1, 2016, Factiva.

198. Official Website for the State of Pennsylvania, PA.GOV, http://www.pa.gov/ (last visited Sept. 29, 2016).

whether to regulate, there is no clear consensus among the fifty states, despite over a half century of regulatory experience.[199] Given such significant diversity, it is natural to ask which regulatory regime (or combination thereof)[200] is normatively desirable, whether in terms of efficiency, fairness, or other criteria.[201] This normative question is not an easy one to answer; answering it would require massive and often unavailable data on the costs, benefits and redistributive effects of the regulation.[202] The difficulty of the inquiry is only further compounded by the considerable scientific uncertainty surrounding causes and effects. Such uncertainty is a basic problem for many emerging technologies, such as nanotechnology[203] and genetically modified organisms.[204]

The same holds true for weather modification. Despite the resources and effort that have been devoted worldwide to the advancement of weather-modification technologies, the process of precipitation formation, and the effect of human intervention, remains quite poorly understood.[205] The most fundamental obstacle

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199. While one might argue that there is a trend towards repeal, Maryland's statutory authorization for county-level weather modification regulations was instituted recently in 2013. *See* MD. CODE § 13-701 (2013). It is also worth noting the recent enactment of weather modifications laws and regulations in other jurisdictions. *See e.g.*, Rengong yingxiang tianqi guanli tiaoli [Regulations on Administration of Weather Modification] (promulgated by St. Council, Mar. 19, 2002, effective May 1, 2002) (P.R.C.).

200. For discussion on the different regulatory approaches, such as disclosure to assist market participants, prohibition or mandating of certain conduct, and restrictions on ownerships, among others, see ROBERT BALDWIN, MARTIN CAVE & MARTIN LODGE, UNDERSTANDING REGULATION: THEORY, STRATEGY, AND PRACTICE 105–33 (2nd ed. 2012); Joseph E. Stiglitz, *Government Failure vs. Market Failure: Principles of Regulation*, *in* GOVERNMENT AND MARKETS: TOWARD A NEW THEORY OF REGULATION 13, 25–32 (Edward J. Balleisen & David A. Moss eds., 2009); Kay et al., *supra* note 71, at 289–01, 312–16.

201. *See* BALDWIN, CAVE & LODGE, *supra* note 200, at 26–31 (discussing the five criteria of legislative mandate, accountability, due process, expertise, and efficiency for good regulation). *See also* John Kay & John Vickers, *Regulatory Reform in Britain*, 3 ECON. POL'Y 285, 303–08 (1988) (discussing the possible goals of efficiency and redistribution, but opining that distributional considerations should be dealt with instruments other than regulation). It is also worth noting that just like how the optimal property rights arrangement depends on the natural resource's particular characteristics and use pattern, the normatively desirable regulatory regime would vary in accordance with specific socioeconomic conditions.

202. *See also* BALDWIN, CAVE & LODGE, *supra* note 200, at 34–37 (discussing the challenges of assessing regulatory quality, such as to how to balance between the different benchmarks arising from conflicting objectives, deciding whether the aspect of the regulation is input, process, outputs, or outcome, to measure, and discerning the causative relationship where there are multiple regulators with overlapping and/or cumulative regulatory function).

203. Eisner, *supra* note 13, at 29–42; JEFFREY H. MATSUURA, NANOTECHNOLOGY REGULATION AND POLICY WORLDWIDE 155–84 (2006).

204. *See* Daele, *supra* note 13, at 118–20 (discussing the complications posed by the perception of risks that can be rather disconnected from actual risks, in the context of genetically modified organisms).

205. GOUDIE, *supra* note 78, at 226–27; Majzoub et al., *supra* note 78, at 341–43; HUTCHINSON & HERRMANN, *supra* note 16, at 54; Kwa, *supra* note 15, at 162.

is simply the natural variability of weather—namely, many of the observed changes in weather conditions (whether short term or long term) are simply naturally-occurring fluctuations.[206] A related reason is the limitations of current technologies. In the best-case scenario, weather modification operations can typically enhance precipitation by ten to twenty percent, with the conjuration of rain in the absence of complementary cloud conditions remaining unattainable.[207] Another obstacle is the double edge of causation: weather modification operators are eager to claim credit for intended weather while at the same time acutely aware of the legal liability that may result from weather-related damages.[208] The lack of coordination between scientific and commercial cloud-seeding operations may also impede accurate analysis; the results, or lack thereof, may have been affected by neighboring weather modification activities.[209]

How regulators should respond to such uncertainty is a substantial issue that is the main inquiry of a companion piece to this Article.[210] This Article takes the preliminary position that the diversity in regulatory approaches is both understandable and desirable, due to the fundamental uncertainty. These diverse approaches are understandable, because one should not expect to observe regulatory convergence when there is no consensus concerning the harms associated with the regulated activity. These approaches are also desirable, because the diversity facilitates a natural experiment to test the efficacy and other practical consequences of the various regulatory approaches.[211]

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206. COTTON & PIELKE, *supra* note 14, at 243–44; Orville, *supra* note 15, at 447–49.

207. GOUDIE, *supra* note 78, at 226–27; Orville, *supra* note 15, at 447–49; Cotton, *supra* note 79, at 141–53; Bartlett, *supra* note 14, at 30. One highly rigorous cloud-seeding experiment included a randomized control over a six year period and found that seeding of appropriate clouds increased precipitation by five to fifteen percent. Alexandra Witze, *Major Clouding-Seeding Test Gives Mixed Results*, NATURE: NEWS (Dec. 11, 2014), http://www.nature.com/news/major-cloud-seeding-test-gives-mixed-results-1.16537.

208. Kwa, *supra* note 15, at 138–39, 148–49; Fleming, *supra* note 16, at 12; Davis, *supra* note 14, at 11–12. *See also* Majzoub et al., *supra* note 78, at 342 ("However, small rainmaker organizations, who work for local farmers, are usually very secretive about when and where they attempt to make rain. The clandestine nature of the cloud seeding business can cause difficulties in tracking down potential defendants in cloud modification cases.").

209. HUTCHINSON & HERRMANN, *supra* note 16, at 49.

210. Jianlin Chen, *Regulating Uncertainty: A Critical Survey of U.S. States' Regulations on Weather Modification* (forthcoming).

211. *See* Michael Greenstone, *Effective Regulation Through Credible Cost-Benefit Analysis: The Opportunity Costs of Superfund*, *in* GOVERNMENT AND MARKETS: TOWARD A NEW THEORY OF REGULATION 52, 53 (Edward J. Balleisen & David A. Moss eds., 2009) (noting the caveat that a rigorous and well-funded review of the "experimentation" of regulation is important to draw the right conclusion and avoid manipulation of the result); MATSUURA, *supra* note 203, at 150–51 (discussing how the benefits of experimenting with different regulatory approaches

B. Property Rights in Cloud Water

Given the instinctive appeal of property rights issues, it should not be surprising that, when the regulatory regime makes any references to atmospheric moisture rights, property rights are one of the first issues addressed. Although it is possible to argue that the broadly worded constitutional and/or statutory provisions of certain states that claim public rights over water might be interpreted to include atmospheric water,[212] five states—Colorado,[213] Louisiana,[214] New Mexico,[215] North Dakota,[216] and Wyoming[217]—have made express declarations of their "sovereign right"[218] to atmospheric moisture. North Dakota's provision comes in a section entitled "[e]xtended state ownership of water sovereignty over

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in the context of nanotechnology—an emerging technology—must be balanced against the initial confusion and inefficiency).

212. *E.g.*, NEV. REV. STAT. § 533.025 (1913) ("The water of all sources of water supply within the boundaries of the State whether above or beneath the surface of the ground, belongs to the public."); *see also* TEX. CONST. art. 16, § 59(a) ("The conservation and development of all of the natural resources of this State, including . . . the preservation and conservation of all such natural resources of the State[,] are each and all hereby declared public rights and duties; and the Legislature shall pass all such laws as may be appropriate thereto.").

213. COLO. REV. STAT. § 36-20-103 (1972) ("The general assembly declares that the state of Colorado claims the right to all moisture suspended in the atmosphere which falls or is artificially induced to fall within its borders. Said moisture is declared to be the property of the people of this state, dedicated to their use pursuant to section 5 and 6 of article XVI of the Colorado constitution and as otherwise provided by law."). These state constitutional provisions establish that the right to divert unappropriated waters (which are property of the public) for beneficial uses shall never be denied, but when faced with scarcity, domestic purposes shall be given top priority, followed by agricultural purposes and then manufacturing purposes. COLO. CONST. art. XVI, § 5 & 6.

214. LA. STAT. ANN. § 37:2201 (1956) ("[T]he state of Louisiana claims its sovereign right to the use for the best interest of its people of the moisture contained in the clouds and atmosphere within its state boundaries.").

215. N.M. Stat. Ann. § 75-3-3 (LexisNexis 1978) ("[T]he state of New Mexico claims the right to all moisture in the atmosphere which would fall so as to become a part of the natural streams or percolated water of New Mexico . . . .").

216. N.D. CENT. CODE § 61-04.1-01 (2010) ("The state of North Dakota claims its sovereign right to use the moisture contained in the clouds and atmosphere within the state boundaries.").

217. WYO. STAT. ANN. § 9-1-905(a)(i) (1951) ("The state of Wyoming claims its sovereign right to the use for its residents and best interests of the moisture contained in the clouds and atmosphere within its sovereign state boundaries."). For a brief discussion of this legislative amendment in the context of overall historical development of Wyoming water laws, *see* Lawrence J. MacDonnell, *The Development of Wyoming Water Law*, 14 WYO. L. REV. 327, 361 (2014).

218. For discussion about how sovereign rights are often regarded as equivalent to property rights, see *supra* note 20.

moisture."[219] Montana stands out in this respect; its state constitution expressly declares all water, including "atmospheric water," to be the property of the state.[220]

In three states—New York, Pennsylvania, and Texas—courts have had the chance to make pronouncements on this issue, albeit to differing degrees. In Pennsylvania, the issue was examined in a full trial by the first-instance court.[221] In Texas[222] and New York,[223] the judgments rendered involved only temporary injunctions, although in Texas the case was eventually appealed to the Texas Supreme Court.[224]

Substantively, the three states' courts came to three quite different conclusions. In New York, the court rejected the claims of a plaintiff seeking a temporary injunction against a resort owner's cloud-seeding operations. The court denied the injunction for, among other legal and factual reasons, the lack of any vested property rights in the clouds or the moisture.[225] Although it thus rejected the idea of private ownership rights over atmospheric moisture, the court did not further clarify or discuss the property rights arrangement. The later Pennsylvania court correctly observed that the New York court's "language concerning vested property rights in clouds and moisture was dicta, unsupported by legal authority or reason."[226] The inconclusive and preliminary character of the court's engagement with the property rights issue, together with the fact that there is no weather modification regulatory regime in the state of New York,[227] limits the relevance of that decision for this Article.

The courts in Texas reached a different conclusion than did their New York counterpart. The courts granted the plaintiff a temporary injunction to restrain weather modification activities over the plaintiff's land, reasoning that a landowner is to be legally protected from improper interference with the natural rainfall, particularly from weather-modification activities that are conducted

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219. N.D. CENT. CODE § 61-04.1-01 (2010).

220. MONT. CONST. art. IX, § 3(3) ("All surface, underground, flood, and atmospheric waters within the boundaries of the state are the property of the state for the use of its people and are subject to appropriation for beneficial uses as provided by law.").

221. Pa. Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 44 Pa. D. & C.2d 749, 749 (1968).

222. Southwest Weather Research, Inc. v. Duncan, 319 S.W.2d 940, 941 (Tex. App. 1958); Southwest Weather Research, Inc. v. Rounsaville, 320 S.W.2d 211, 213 (Tex. App. 1958).

223. Slutksy v. City of New York, 97 N.Y.S. 2d 238 (1950).

224. Southwest Weather Research, Inc. v. Jones, 327 S.W.2d 417 (Tex. Supreme Ct. 1959).

225. 97 N.Y.S. 2d 238, 239 (1950).

226. *Pa. Nat. Weather Ass'n*, 44 Pa. D. & C.2d at 757.

227. *Supra* Part IV.A.2.

directly over his or her land.[228] Notably, although the judgment came only in the context of granting a preliminary injunction, rather than as the result of a full trial, the trial court and the court of appeals "carefully considered the voluminous record and exhibits that were admitted in evidence" and discussed the various legal authorities and scholarly literature on the issue.[229]

A decade after the Texas decisions, the Pennsylvania court adopted something of a hybrid approach. After discussing the New York and Texas actions and addressing a copious amount of scholarly literature, the court held that because "[m]oisture in the clouds is common property belonging to everyone who will benefit from what occurs naturally in the clouds . . . [e]very owner of land has a property right in the moisture in the clouds and the right to receive that moisture in its natural form subject to such weather modification activities as shall be carried out by governmental authorities in the public, as opposed to private, interest."[230] That holding granted the landowner rights akin to those granted by the Texas court, but with explicit subjugation to the public interest that reflects the rationale of the New York courts.[231] In addition, the Pennsylvania court held that when adequate remedies are provided—in that case, statutory damages as determined by the regulatory authority[232]—there exists no equitable right to an injunction.[233]

In sum, six states have made legislative or constitutional claims to sovereign property rights in atmospheric moisture, while the courts in two states have declared that landowners possess private rights to the atmospheric moisture above their land.

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228. Southwest Weather Research, Inc. v. Duncan, 319 S.W.2d 940 (Tex. App. 1958); Southwest Weather Research, Inc. v. Rounsaville, 320 S.W.2d 211 (Tex. App. 1958). Both cases are affirmed together in *Jones*, 327 S. W.2d.

229. *Duncan*, 319 S. W.2d at 943–44; *Rounsaville*, 320 S. W.2d at 215–16. The Texas Supreme Court took pains to emphasize the provisional nature of the lower courts purported holding and finding, and stressed the appeals court reviewed for abuse of discretion. *Jones*, 327 S. W.2d at 421.

230. *Pa. Nat. Weather Ass'n*, 44 Pa. D. & C.2d at 763.

231. Slutksy v. City of New York, 97 N. Y. S. 2d 238, 240 (1950) ("This court must balance the conflicting interests between a remote possibility of inconvenience to plaintiffs' resort and its guests with the problem of maintaining and supplying the inhabitants of the City of New York and surrounding areas, with a population of about 10 million inhabitants, with an adequate supply of pure and wholesome water.").

232. *Supra* notes 190–197 and accompanying text.

233. *Pa. Nat. Weather Ass'n*, 44 Pa. D. & C.2d at 764.

C. Relationship Between Property Rights and Regulation

What, then, is the relationship, if any, between a state's pronouncements of property rights in atmospheric moisture and the regulatory regime of that state?

1. The Irrelevance of State Ownership

The most counterintuitive finding is that a state's express assertion of state ownership over atmospheric moisture bears little relation to the corresponding regulatory regime, both in terms of the regime's redistributive characteristics and in terms of the extent of the regime's control. Initially, one might expect that such a declaration would be accompanied by the imposition of substantially larger permit/license fees to reflect the granting of privileges to harness these ostensibly publicly owned natural resources.[234] However, among the six states (Colorado, Louisiana, Montana, New Mexico, North Dakota, and Wyoming) that contain such express statutory or constitutional declarations, Montana alone charges substantial fees for the permits that seek to tap into this natural resource.[235] Conversely, the other three states that charge substantial fees for the regulatory permits—Nevada, Washington and Wisconsin[236]—do so in the absence of such declarations. The small sample size precludes any meaningful statistical inquiry, but the fact that substantial fees are actually levied by a higher ratio of states without such a declaration (1:4 vs 1:6) does suggest that the expectation that greater redistribution will arise from state ownership of a natural resource may be unfounded, at least in the context of weather modification. Indeed, it is interesting that North Dakota, which has the most strongly worded provision (i.e., a direct claim of "state ownership") in its weather modification regulation, is also one of only three states in which the obligation (and consequential

234. Chen & Cui, *supra* note 4, at 91–92 (discussing the public perception that the declaration of state ownership over wind and sunlight by a provincial government in China was intended to generate revenue through permit fees); Maniruzzaman, *supra* note 21, at 83–85 (discussing the various manifestations of resource nationalism, including nationalizing the relevant industry sector, that are driven by the states' desire for a greater share in the profits of their natural resources).

235. *Infra* Part IV.A.5. Relatedly, note that in stark contrast with the lax position over use of atmospheric moisture, Wyoming is actually the first U.S. state to impose a tax on wind energy production in the state, purportedly for "the privilege of producing electricity from wind resources" in Wyoming. Walter Wang, *Challenging State Taxation of Renewable Energy: Will Wyoming be the Battleground?*, 15 LEWIS & CLARK L. REV. 451, 455–56 (2011).

236. *Infra* Part IV.A.5.

costs) of public notification are borne by the regulatory authorities, to the significant benefit of applicants.[237]

Similar indeterminacy can be observed when it comes to the various possible regulatory burdens. Assertion of state ownership has often been seen as a prelude to more aggressive regulatory control over the use of natural resources,[238] but Louisiana and Wyoming are among the four states that do not have the requirement of financial responsibility as a condition of regulatory approval.[239] There is a disproportionate absence of the significant costs of providing insurance, corporate surety bond, or cash deposit in conjunction with the application among states with state ownership of atmospheric moisture (1:3 vs 1:6). In a similar vein, there are no obligations of public notification in Louisiana, New Mexico, and Wyoming; these three form the majority of the five states that do not have such requirements.[240]

2. Constraints of Private Rights

This seeming independence of state ownership and the form of regulatory regime stands in contrast to private ownership of atmospheric moisture. In Texas and Pennsylvania—states whose courts, as explained above, have granted landowners certain rights over atmospheric moisture[241]— the regulatory regimes contain unique provisions that are unique to those states. In Texas, the regulatory authority must first find "that the weather modification and control operation as proposed in the permit application will not significantly dissipate the clouds and prevent their natural course of developing rain in the area in which the operation is to be conducted to the material detriment of persons or property in that area."[242] This specific requirement contrasts with other states' provisions, which either have vague language concerning the promotion

237. *Infra* Part IV.A.5.

238. Pinto, *supra* note 21, at 997–98 (comparatively discussing the Brazilian and American legal regime on hydrocarbon ownership and arguing that "public ownership of hydrocarbons provides the government with more flexibility to foster national policy goals as expressed, for example, by the local content requirement of Brazil's regulation"); Chen & Cui, *supra* note 4, at 91–92 (discussing the public perception that the declaration of state ownership over wind and sunlight by a provincial government in China was in fact an attempt to expand regulatory power).

239. *Infra* Part IV.A.3.

240. *Infra* Part IV.A.4.

241. *Infra* Part IV.B.

242. TEX. AGRIC. CODE § 301.107(a) (2004).

of general public welfare[243] or lack specific conditions beyond professional qualifications, financial responsibility, and/or public notification.[244]

Similarly, Pennsylvania has an explicit statutory provision for administratively-determined compensation liability for landowners harmed by adverse weather effects arising from approved weather modification activities. This provision is sui generis: other states either leave civil liability unresolved or alter civil liability in a way that does not unambiguously provide affected landowners with a right to claim damages for adverse weather effects from approved weather-modification activities.[245]

Although different in content and form, the Texas and Pennsylvania provisions are conceptually similar: both are designed to safeguard landowner rights over atmospheric moisture. The Texas provision is essentially protecting the landowner's rights via an inalienability rule,[246] because the regulator must make a finding of no detriment without any explicit provision made for the possibility of consent by the affected landowners.[247] Of course, if in practice the regulator would consider evidence of consent by the affected landowners (e.g., written agreement procured by valuable considerations or otherwise) as evidence of no detriment, then the protection would be more akin to a property rule protection. Conversely, the Pennsylvania provision utilizes a liability rule to protect landowner rights. The landowner is granted the explicit right to monetary compensation for damages caused by weather-modification activities but lacks any other manifestation of that right. The regulator granting the license need not address potential harms that the proposed weather-modification activities might cause to

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243. *E.g.*, OR. REV. STAT. § 558.060(1) (2015) ("(b) The production, management or conservation of water or energy resources or agricultural or forest crops could be benefited by the proposed weather modification operation; and (c) The proposed weather modification operation would not be injurious to the public health or safety."); WASH. STAT. § 43.37.110(5) (1973) ("for the general welfare and public good"); WIS. STAT. §93.35(6)(d)(3) (2012) ("is reasonably conceived to improve water quality or quantity, reduce losses from weather hazards, provide economic benefits to the people of this state, advance or enhance scientific knowledge or otherwise carry out the objectives and purposes of this section").

244. *E.g.*, ARIZ. REV. STAT. § 45-1603(A) (LexisNexis 2012); FLA. STAT. ANN. § 403.331(1) (LexisNexis 2014).

245. *Infra* Part IV.A.6.

246. An inalienability rule is where the law decides both who the entitlement owner is and prohibit even voluntary transfer of the entitlement. Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, And Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089, 1111–15 (1972).

247. TEX. AGRIC. CODE § 301.107(a) (2004).

neighboring land,[248] and courts will not grant an injunction, because monetary damages are available.[249]

3. Disparate Legal Effect

The differential effect of property rights on the corresponding regulatory regime should not come as a surprise. Although there is a common and understandable concern that declarations of state ownership are often a pretext for expanding government/regulatory power over private conduct that has traditionally been free from state interference,[250] there are usually no legal constraints that dictate that outcome. Unlike the ubiquitous federal and state constitutional protections against takings of private property,[251] legal restrictions on the disposition of state-owned property are fairly uncommon, at least in common law jurisdictions.[252] And even when such legal restrictions do exist (such as in anti-donation clauses found in several U.S. states[253]), they tend to be thinner in breadth

248. 3 PA. STAT. ANN. § 1106 (LexisNexis 2008).

249. *Supra* notes 228–231 and accompanying text.

250. Such concerns and such arguments are commonly raised even outside of the United States. They have been raised, for example, by opponents of a provincial regulation in China that declares climate resources (defined to include wind energy, solar energy and atmospheric water) to be property of the state. *See* Chen & Cui, *supra* note 4, at 92–93 (2013).

251. U.S. CONST. amend. V. For a survey of constitutional protections among the states, see JULIUS SACKMAN ET AL., NICHOLS LAW ON EMINENT DOMAIN, Ch. 6 § 6.01(12)(c) (3d ed. 2008).

252. In modern civil law jurisdictions such as France and Germany, a category of publicly owned property exists that cannot be readily privatized. Known as "public property proper" in Germany (as distinguished from "public financial assets") and "state public property" in France (as distinguished from "state-owned private property"), these properties either have a beneficial function to the public or are directly utilized by the public. Examples include public roads, parks, and navigable rivers. Patrice Chretien, *The Property of Public Bodies*, *in* THE PUBLIC-PRIVATE LAW DIVIDE: POTENTIAL FOR TRANSFORMATION? 311, 316–25 (Matthias Ruffert ed., 2009); Laurent Aynés, *Property Law*, *in* INTRODUCTION TO FRENCH LAW 148 (George A. Bermann & Etienne Picard eds., 2008); MURRAY RAFF, PRIVATE PROPERTY AND ENVIRONMENTAL RESPONSIBILITY: A COMPARATIVE STUDY OF GERMAN REAL PROPERTY LAW 161–62 (2003); JOHN BELL ET AL., PRINCIPLES OF FRENCH LAW 282 (1998). This approach reflects the civilian conceptualization of public property, which is based on public use and which can be traced to Roman Law. Giacinto della Cananea, *From (Public) Ownership to Use: A Comparative Analysis*, *in* THE PUBLIC-PRIVATE LAW DIVIDE: POTENTIAL FOR TRANSFORMATION?, *supra*, at 297, 299–301; Rose, *supra* note 106, at 96–100.

253. Anti-donation clauses attempt to limit sub-market value transfers of public property to private entities. Jurisdictions with such clauses include New York, *see* N.Y. CONST. art. VIII, § 1 ("No county, city, town, village or school district shall give or loan any money or property to or in aid of any individual, or private corporation or association, or private undertaking . . . [subject to various exceptions]") and Washington State, see WASH. CONST. Art. VIII, § 7 ("No county, city, town or other municipal corporation shall hereafter give any money, or property, or loan its money, or credit to or in aid of any individual, association, company or corporation, except for the necessary support of the poor and infirm, or become directly or

and depth. In general, either satisfaction of public purpose or valuable consideration will suffice to allow a state to transfer ownership of its state-owned property. This contrasts with the need for both public purpose *and* adequate compensation in order to take private property.[254]

Conversely, the more robust constitutional protections given to private property mean that, when a private entity holds private rights to a natural resource, any regulatory control or state interference with the use of that natural resource may be subject to considerably greater legal constraints. At first glance, then, the focus of this Article—the relationship between property rights and regulation—might seem to call for a lengthy discussion of regulatory takings. But the existing doctrines of regulatory takings cannot easily explain the effect of private rights on the regulatory regimes in Texas and Pennsylvania. Although regulatory-taking claims do cast a shadow over legislative or regulatory endeavors that might diminish the economic value of private property, the high threshold for actionable regulatory takings—a regulatory taking is usually only actionable if it stands to extinguish all economically viable activities on the land[255]—means that the state remains amply endowed with general regulatory and taxing powers to address the

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indirectly the owner of any stock in or bonds of any association, company or corporation."). For discussion of the origins and limitations of such clauses, see John Martinez, *Getting Back the Public's Money: The Anti-Favoritism Norm in American Property Law*, 58 BUFF. L. REV. 619, 653–59 (2010); Charles W. Godner, Jr., *State and Local Government Fiscal Responsibility: An Integrated Approach*, 26 WAKE FOREST L. REV. 925, 927–38 (1991).

254. *See, e.g.*, Citizens Protecting Resources v. Yakima County, 152 Wash.App. 914, 920 (Wash. App. 2009) (discussing the two-pronged analysis that first examines whether the transfer is for "a fundamental purpose of the government", and if is not, proceeds to examine whether sufficient consideration has been or will be received by the government). *See* Martinez, *supra* note 253, at 662–71 (sketching an "anti-favoritism" norm in the U.S., and proposing a legal test whereby any transfer of public asset must be either accompanied by either sufficient monetary consideration or for a public purpose). For a critical discussion about how judicial deference in interpreting the "public purpose" requirement has essentially nullified the requirement, see Richard Briffault, *The Disfavored Constitution: State Fiscal Limits and State Constitutional Law*, 34 RUTGERS L.J. 907, 910–15 (2003); Dale F. Rubin, *Public Purpose in the Northwest: A Sinkhole of Judicial Interpretation—the Case for Alternatives in the Delivery of Public Services and the Granting of Subsidies*, 32 IDAHO L. REV. 417, 420–30 (1996).

255. STEVEN J. EAGLE, REGULATORY TAKINGS 153–214 (Lexis Nexis 3rd ed. 2005). In the context of land use and environmental protection, see ROBERT MELTZ, DWIGHT H. MERRIAM & RICHARD M. FRANK, THE TAKINGS ISSUE: CONSTITUTIONAL LIMITS ON LAND-USE CONTROL AND ENVIRONMENTAL REGULATION (1999). Around the world, most countries typically have a similar or higher threshold to establish an actionable regulatory taking. *See* Matthew C. Porterfield, *State Practice and the (Purported) Obligation Under Customary International Law to Provide Compensation for Regulatory Expropriations*, 37 N.C. J. INT'L L. & COM. REG. 159, 171–86 (2011) (surveying selected countries' regulatory-takings doctrines); Michael Wilkinson, *Land*, *in* LAW OF THE HONG KONG CONSTITUTION 359, 392–94 (Johannes Chan & C.L. Lim eds., 2011) (discussing the U.S.-style standard adopted in Hong Kong). *See also* Rachelle Alterman, *When the Right to Compensation for "Regulatory Takings" Goes to the Extreme: The Case of Israel*, 6

negative externalities and redistribution concerns arising from the use of natural resources, even when the natural resource in question is privately owned.[256] In a previous case study on emerging natural resources and the nationalization of wind and sunlight,[257] it was discovered that, regardless of whether the common law *ad coelum* rule[258] is applied to wind and sunlight, their utilization is susceptible to all sorts of restrictions (whether under common law[259] or via regulatory powers[260]) and taxes.[261]

What distinguishes atmospheric moisture from both wind and sunlight is the manner in which the resource is used. Capture of the available wind and sunlight over a plot of land is typically achieved through physical installations (wind turbines and solar panels) on the particular plot of land. Although such resource utilization can generate negative externalities to adjacent land[262]—including negatively affecting similar utilization of the resource on neighboring

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WASH. U. GLOBAL STUD. L. REV. 121, 152 (2007) (discussing of the Israeli regulatory-takings doctrine, which is substantially more generous to private-property owners).

256. Chen & Cui, *supra* note 4, at 127. *See also* Andrew W. Schwartz, *No Competing Theory of Constitutional Interpretation Justifies Regulatory Takings Ideology*, 34 STAN. ENVTL. L.J. 247, 250–52 (2015) (arguing that the expanded notion of regulatory takings in current U.S. jurisprudence is not only unjustifiable on constitutional grounds, but also unduly constrains much-needed regulatory responses to environmental problems).

257. Chen & Cui, *supra* note 4.

258. Rule, *supra* note 3, at 806; DuVivier, *supra* note 102, at 75–77; Spranking, *supra* note 2, at 982–85.

259. Nuisance is the prime example, see MURPHY, *supra* note 50, at 5–7; Mortensen et al., *supra* note 50, at 223. However, the public-trust doctrine has also been employed to restrict wind- and solar-energy projects. *See* Alexandra B. Klass, *Renewable Energy and the Public Trust Doctrine*, 45 U.C. DAVIS L. REV. 1021, 1027–32 (2012); Richard J. Lazarus, *Changing Conceptions of Property and Sovereignty in Natural Resources: Questioning the Public Trust Doctrine*, 71 IOWA L. REV. 631, 633–56 (1986).

260. Patricia Salkin, *The Key to Unlocking the Power of Small Scale Renewable Energy: Local Land Use Regulation*, 27 J. LAND USE & ENVTL. L. 339, 354–60 (2012); Troy A. Rule, *Renewable Energy and the Neighbors*, 2010 UTAH L. REV. 1223, 1226–28 (2010). For a discussion of environmental lawsuits that have challenged renewable-energy projects by using environmental laws such as the National Environmental Policy Act, the Endangered Species Act, Clean Water Act, National Historic Preservation Act, and others, see John Copeland Nagle, *Green Harms of Green Projects*, 27 NOTRE DAME J.L. ETHICS & PUB. POL'Y 59, 73–88 (2013). For a comparative discussion of regulatory approaches in other countries, see Mortensen et al., *supra* note 50.

261. The tax could be a general tax on the profits arising from resource utilization: Morriss, Meiners & Dorchak, *supra* note 49, at 757. There could also be specific natural-resource tax. Wang, *supra* note 235, at 455–56 (discussing Wyoming's tax on wind energy production, a rarity). *See also* Keith J. Brewer, Stephen E. Hamilton & Richard A. Westin, *Economic Approaches to Nonrenewable Resource Taxation*, 11 J. NAT. RESOURCES & ENVTL. L. 175, 188–93 (1995) (discussing the various methods of taxing natural resources from an economic perspective); Walter Hellerstein, *Political Perspectives on State and Local Taxation of Natural Resources*, 19 GA. L. REV. 31, 32–35 (1984) (discussing the various natural resources taxes implemented by the states and the political controversies that accompanied them).

262. Nagle, *supra* note 260, at 66–69; Matthew K. McCasland, *Windy City Heat: How Wind Energy Can Help Power Illinois Into the Future*, 2012 U. ILL. J.L. TECH. & POL'Y. 167, 182–85 (2012); Rule, *supra* note 260, at 1238.

land[263]—no direct physical intrusion into adjacent lands is usually necessary to harness the resources.

Not so with weather modification activities. Successfully effecting a desired weather phenomenon on a given plot of land usually requires undertaking physical activities over the surrounding land. Optimally timing and siting the dispersal of chemicals for cloud seeding requires the would-be weather modifier to consider the direction and strength of prevailing winds as well as the time it will take for the induced atmospheric effect to manifest itself.[264] And the structure of the cloud system forms yet another important variable that impacts where the chemical should be dispersed.[265] In addition, even the smallest weather-modification operations require treatment over several hundred hectares (several square kilometers).[266] When inducing snow, moreover, the targeted area for weather modification may be far upstream from the intended beneficiaries, who seek to benefit from extra water when the snow eventually melts.[267] These cross-boundary concerns are amply evidenced in *Nd Atmos. Res. Bd. V. Bnrc*,[268] a judicial review of litigation concerning a Montana weather-modification permit. There, the applicant for the permit (the state of North Dakota) wanted to conduct cloud seeding as far as 20 miles inside the Montana border in order to increase precipitation within North Dakota.[269]

Thus, the legal constraints that private rights to atmospheric moisture impose on the weather-modification regulatory regime are those of physical takings, not simply of regulatory takings. In essence, a typical weather-modification license or permit authorizes a private party to physically access and interfere with atmospheric moisture over land that does not belong to the intended beneficiaries. If no provisions are made to protect the property rights of these landowners (be it a property-rule veto or liability-rule compensation), then a regulatory regime that authorizes weather-modification activities beyond the property lines of the applicant

263. For example, wake turbulence from a wind turbine can diminish wind flow to wind turbines located downwind. *See* Alan J. Alexander, *The Texas Wind Estate: Wind as a Natural Resource and a Severable Property Interest*, 44 U. MICH. J.L. REFORM 429, 438 (2011); Yael Lifshitz-Goldberg, *Gone with the Wind? The Potential Tragedy of the Common Wind*, 28 UCLA J. ENVTL. L. & POL'Y 435, 455–60 (2010).

264. COTTON & PIELKE, *supra* note 14, at 16; Czys, DeFelice & Griffith, *supra* note 87, at 66–70.

265. COTTON & PIELKE, *supra* note 14, at 14–15, 24; Czys, DeFelice & Griffith, *supra* note 87, at 69–70.

266. DeFelice & Keyes, *supra* note 97, at 1.

267. Keyes, *supra* note 82, at 13–14.

268. 1992 Mont. Dist. LEXIS 60 (Mont. Dist. Ct. 1992).

269. *Id.*, at *2.

risks being construed as an unconstitutional taking without compensation.[270]

IV. STATE PROPERTY AND TRANSITION

The findings of the case study discussed in the previous Part highlight an important aspect of transition. The various forms of ownership bring significantly different legal impediments to the use of particular regulatory controls. That is, choosing to implement a certain property rights arrangement may preclude choosing certain control mechanisms. In the case of atmospheric moisture, state ownership neither limits nor influences the regulatory regime, whereas private-property rights require distinct accommodation from the regulatory regime. Building on this finding, this Part of the Article examines more closely the relative ease of transitions among the different forms of property ownership. It argues that state ownership enjoys two distinct advantages over other arrangements: first, state ownership is the easiest form from which to transition to other property rights arrangements; and second, state ownership allows more holistic transitions, given that an optimal transition typically requires modifying both the form of property ownership and the corresponding control mechanisms.

A. Ease of Transition

Three dimensions of state property facilitate transition to other property rights regimes. First, and perhaps most obvious, is the legal dimension, which was examined in Part III.C. Notably, the constitutional protection of private property might apply to certain communally-owned property and anticommons rights held by private entities, particularly if accompanied by an expanded definition

270. In this respect, a comparison can be made with the controversies surrounding so-called "right-to-farm" legislation, which sought to limit the nuisance claims that could be brought against a farm owner. Although such legislation is most often paired with a regulatory regime that prescribes minimum standards of agricultural practices that a farmer must comply with to enjoy protection from nuisance suits, such legislation arguably infringes on the property rights of neighboring landowners, by permitting a farm owner to infringe upon their right of quiet enjoyment. Accordingly, some state courts have invalided right-to-farm statutes as unconstitutional takings, given the extensive immunity to nuisance suits they bestow upon farmers. *See* Jason Jordan, *A Pig in the Parlor of Food on the Table: Is Texas's Right to Farm Act an Unconstitutional Mechanism to Perpetuate Nuisances or Sound Public Policy Ensuring Sustainable Growth?*, 42 TEX. TECH L. REV. 943, 957–63 (2010); Terence J. Centner, *Governments and Unconstitutional Takings: When Do Right-to-Farm Laws Go Too Far?*, 33 B.C. ENVTL. AFF. L. REV. 87, 117–35 (2006).

of private property.[271] In addition to the lack of incentives (and perhaps standing) for an individual citizen to litigate the improper disposition of state property (compared with the willingness and ability of property owners to assert their legal rights against state interference), there are significantly fewer legal obstacles to transitions away from state property.

Second, political opposition to transfers of state property tends to be less vigorous than opposition to the modification of private-property rights. Although changes to property rights arrangements may be efficient, redistribution among the existing and new entitlement holders is almost inevitable, usually to the detriment of existing entitlement holders.[272] Public-choice theory predicts that interest-group politics will lead to outcomes favorable to well-organized minority interest groups, as their stakes in the political outcome outweigh those of the general public.[273] When the losses that the transition causes to existing entitlement holders are concentrated, and when the gains of the new entitlement holders are diffuse, political opposition to the transition is likely to outweigh political support (even before cognitive bias against loss aversion is factored in[274]). From this perspective, the political inertia marking different types of property rights transitions is highly asymmetric, with transitions from a more diffused ownership structure to a concentrated ownership structure being more politically feasible than the reverse. Thus, public-choice theory implies that, all else being equal, transitions away from private property and anticommons to

271. *See* Frederick E. Ellrod III & Nicholas P. Miller, *Property Rights, Federalism, and the Public Rights-of-Way*, 26 SEATTLE U.L. REV. 475, 483–85, 500–01 (2003) (arguing that public rights-of-way enjoyed by local communities are proprietary interests whose uncompensated deprivation would violate the Takings Clause). It is also worth noting that eminent domain of publicly owned property by a higher-level government is also subject to the just-compensation requirement, despite no express reference to public property. *See* United States v. 50 Acres of Land, 469 U.S. 24 (1984); Michael H. Schill, *Intergovernmental Takings and Just Compensation: A Question of Federalism*, 137 U. PA. L. REV. 829, 831 (1989).

272. *See* Levmore, *supra* note 12, at 433; Wyman, *supra* note 12, at 123–25.

273. *See* DENNIS C. MUELLER, PUBLIC CHOICE III 131–33 (3rd ed. 2003); Samuel Issacharoff, *Democracy and Collective Decision Making*, 6 INT'L J. CONST. L. 231, 257–58 (2008); James D. Gwartney & Richard E. Wagner, *Public Choice and the Conduct of Representative Government*, *in* PUBLIC CHOICE AND CONSTITUTIONAL ECONOMICS 1, 19 (James D. Gwartney & Richard E. Wagner eds. 1988); William N. Eskridge, Jr., *Politics Without Romance: Implications of Public Choice Theory for Statutory Interpretation*, 74 VA. L. REV. 275, 294–95 (1988).

274. *See* Kevin Arceneaux, *Cognitive Biases and the Strength of Political Arguments*, 56 AM. J. POL. SCI. 271, 272–73, 282–83 (2012) (discussing the cognitive bias in favor of political arguments framed as loss aversion); J. D. Trout, *Paternalism and Cognitive Bias*, 24 L. & PHIL. 393, 395–408, 433–34 (2005) (discussing the various types of cognitive bias and arguing that certain forms of state decision-debiasing intervention promotes individual autonomy).

commons are less probable than transitions in the opposite direction.[275]

At first glance, the political inertia against transitions away from state-owned property may seem significant. After all, there is a single clearly identified entitlement holder (the state) to the property. But the state at the same time is an entity that purports to represent the most diffuse of interests: the entire population.[276] It is precisely the structure of the owner, a single entity representing extremely diffuse interests, that minimizes political opposition. Individual losses to the purported beneficiaries (i.e., the individual citizens) are often minimal and physically remote. All else equal, this diffuseness severely reduces both the incentives for, and capabilities of, opposing transitions away from state ownership. Conversely, the existence of a formal governing entity representing the diffuse interests also solves the collective-action and holdout problems that might otherwise hinder transitions.[277] It is true, of course, that state property is sometimes subject to ideological constraints that can galvanize and empower political opposition against certain transitions. Examples range from the well-known (for example, socialist hostility to privatization[278]) to the more subtle (how association of public access with public property can block adoption of market-based allocation mechanisms for a public road[279]). And ideological

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275. *Cf.* David Fagundes, *Property Rhetoric and the Public Domain*, 94 MINN. L. REV. 652, 654–56 (2010) (noting the disparity between the intense public reaction over the perceived deprivation of private property in *Kelo* vis-à-vis the public indifference regarding the massive removal of intellectual property from the public domain). *See also* Heller, *supra* note 9, at 631 ("private property emerges more successfully in resources that begin transition with a single owner holding a near-standard bundle of market legal rights"). *See generally* Levmore, *supra* note 12, at 433–50 (discussing the several examples of devolution—though usually only partial—away from private property).

276. *See, e.g.*, تونس دستور [Constitution of the Tunisian Republic], 2014, art. 13 ("Natural resources belong to the people of Tunisia. The state exercises sovereignty over them in the name of the people."); XIAN FA [Constitution of the People's Republic of China], 2004, art. 9 ("All mineral resources, waters, forests, mountains, grasslands, unreclaimed land, beaches and other natural resources are owned by the state, that is, by the whole people"). *See* Heller, *supra* note 25, at xvi ("State property resembles private property in that there is a single decision maker but differs in that resource use is directed through some process that is, in principle, responsive to the needs of the public as a whole.").

277. *See* Banner, *supra* note 60, at 362–65; Field, *supra* note 24, at 335–40.

278. In China, for example, publicly owned property continues to be viewed as a fundamental pillar of the Chinese state even in the midst of the transition to a "socialist market economy" and the increased recognition of the economic contributions from privately owned entities. *See* Article 3, Wuquan fa [Property Law] (promulgated by Nat'l People's Cong., Mar. 16, 2007, effective Oct. 1, 2007) (P.R.C.); Zhongguo jingji tizhi gaige 30 nian huigu yu zhanwang [30 YEARS OF ECONOMIC REFORM IN CHINA: REFLECTING AND LOOKING AHEAD] 42 (Wei liqun ed., 2008).

279. *See* Carlos Sun, *The Toll Road Not Taken: Could the One Option Less Used Make a Difference?*, 21 KAN. J.L. & PUB. POL'Y. 280, 284 (2012); Joseph D. Kearney & Thomas W. Merrill,

constraints are by no means unique to state-owned property; they may similarly impact other property rights arrangements.[280]

Third, and perhaps least appreciated, state ownership of a particular resource or property will invariably involve forms of property rights transition. This aspect could actually be garnered from the definition of state ownership vis-à-vis other property rights arrangements such as private property and commons. The classic theoretical trilogy of "ownership" distinguishes between three ideal types of ownership: private property, commons property, and state property.[281] Under this model, a property or resource is state-owned when the state is the entity tasked with managing that property or resource.[282] When a different arrangement of property rights would lead to more efficient resource utilization, the state, as manager of the resource, should in theory adopt those property rights arrangements as a resource-management strategy, in order to advance the interests of the state.[283] The state's interests would be advanced from such socially efficient transitions either through revenue generation (whether direct, at the time of the initial allocation, or indirect, through taxes on receipts or income) or by the theoretical conceptualization of the interest of the state as encompassing the overall social welfare within its jurisdiction. Notably, although the former (i.e., revenue generation capturing the efficiency gain) might be possible for certain transitions from more concentrated to

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Private Rights in Public Lands: The Chicago Lakefront, Montgomery Ward, and the Public Dedication Doctrine, 105 NW. U.L. REV. 1417, 1521 (2011).

280. *See* Butler, *supra* note 63, at 876–90 (critically discussing the increasingly powerful narratives by private property rights advocates and arguing that these advocates' influence increasingly limits the flexibility and ability of government to promote public goods).

281. Katrina M. Wyman, *The Property Rights Challenge in Marine Fisheries*, 50 ARIZ. L. REV. 511, 530 (2008); Michael A. Heller, *The Dynamic Analytics of Property Law*, 2 THEORETICAL INQUIRIES L. 79, 82–86 (2001); JEREMY WALDRON, THE RIGHT TO PRIVATE PROPERTY 37–42 (1988). For a recent critical comparison of this trilogy with other property theories, see Sarah E. Hamill, *Private Rights to Public Property: The Evolution of Common property in Canada*, 58 MCGILL L.J. 365, 369–80 (2012). *See also* Bruce Yandle & Andrew P. Morriss, *The Technologies of Property Rights: Choice Among Alternative Solutions to Tragedies of Commons*, 28 ECOLOGY L.Q. 123, 129 (2001) (adding two further categories to the trilogy: "commons" (property available to all mankind) and "regulatory property" ("a property right created and allocated by a government entity")).

282. *See* Heller, *supra* note 25, at xvi; Rose, *supra* note 41, at 719–20; Demsetz, *supra* note 24, at 354.

283. *See* Jianlin Chen & Jiongzhe Cui, *More Market-Oriented Than the United States And More Socialist Than China: A Comparative Public Property Story of Singapore*, 23 PAC. RIM L. & POL'Y J. 1, 54 (2014) ("Public property, the otherwise sacred poster child of socialist regimes, is simply a form of property. If market mechanisms represent the most effective form of property allocation to ensure that public property is not squandered—and often they do—then an emphasis on public property protection will necessarily imply the widespread use of market mechanisms.").

more diffused property rights arrangements,[284] the latter (i.e., a broad definition of "self-interest" to include social gains and losses) inevitably decrease as the property rights arrangements become more concentrated. In practice, this dynamic is much more prevalent than is commonly presumed, as will be discussed in conjunction with the next Part's dispelling of the undeserved association of state property with socialism.

B. Holistic Transition

Closely related to ease of transition is another benefit of state ownership: when a state attempts to implement more efficient resource-management, it can typically effect simultaneous changes in both ownership and control mechanisms. Thus, the state can better coordinate and calibrate the two. The manifestation of coordination can be seen in the U.S.'s management of federally-owned lands. Throughout the history of federal ownership of land, land has been allocated and utilized in a wide variety of ways. Approaches have ranged from full transfers of ownership rights to private entities—either to generate revenue through sale or to serve certain government policy objectives (e.g., settlement of the West via the Homestead Act)[285]—to allocation or licensing schemes. Under the latter schemes, the state retains title to the land, but private entities are allowed to acquire property rights interests, usually upon satisfaction of statutory conditions tailored to specific policy considerations.[286]

With other property rights arrangements, by contrast, altering the control mechanisms is often the only practical way to achieve certain outcomes, because of the inertia against changes to existing ownership structure. Consider, for example, private land that contains an ecologically sensitive habitat for endangered species and other natural heritages. Given the stark misalignment of incentives

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284. *See* Levmore, *supra* note 12, at 426–29 (discussing how "private properties, with restricted access supporting various residential and commercial uses, might have turned into a contiguous green belt, with fairly open access but quite limited use").

285. Huber, *supra* note 69, at 1023–24; Michael I. Jeffery, *Public Lands Reform: A Reluctant Leap into the Abyss*, 16 VA. ENVTL. L.J. 79, 82–89 (1996). For a historical overview, see Paul W. Gates, *An Overview of American Land Policy*, 50 AGRIC. HIST. 213, 217–20 (1976).

286. For an examination of the different types of private interests that may be created in publicly owned resources and that may be deemed as property for the purpose of the Takings Clause, *see* Jan G. Laitos & Richard A. Westfall, *Government Interference with Private Interests in Public Resources*, 11 HARV. ENVTL. L. REV 1, 12–19, 64–65 (1987); *see also* Ellrod & Miller, *supra* note 271, at 504–05 (observing that government can act as either a regulator or a property owner, and noting that the two functions are easily confused).

and benefits (preserving such lands would be of great social value, while developing them would bring largely private gains), the optimal combination of property ownership and control mechanism in such a situation would arguably be either public ownership paired with a limited quota or paid licenses to private entities for prescribed use of or access to the land,[287] or communal ownership paired with mechanisms that allow the community to derive sufficient economic benefit from preservation (for example, by allowing ecotourism), thus creating incentives for sustainable management of the natural heritage.[288] But because of the high costs of transitioning away from private ownership—given both the compensation that must be paid for a taking under eminent domain and the other sources of inertia discussed in the previous section—regulatory controls (e.g., the Endangered Species Act) will be the only practically available option.[289]

Indeed, the greater the ability to coordinate ownership and control mechanisms, the better the prospects of implementing the optimal resource-management strategy. As observed in Part I.B., *supra*, the ownership structure alone, whether commons, private property, anticommons, or otherwise, does not determine whether the ultimate outcome is "tragedy." Appropriate control mechanisms can very often mitigate the externalities that might otherwise arise from the ownership structure. Even so, ownership structure and control mechanisms are never perfect substitutes. Each strategy will have relative advantages and disadvantages, which will vary according to the characteristics of the resource in question.[290] When, for example, the property has boundaries that are easy to verify and the

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287. This is essentially the modern management strategy for national parks, which is designed to combat both the diminishment of enjoyment of park visitors and the degradation of the natural environment caused by overcrowding arising from increased demand. *See* Catherine M. Pickering & Ralf C. Buckley, *Swarming the Summit: Managing Tourists at Mt Kosciuszko, Australia*, 23 MOUNTAIN RES. & DEV. 230, 232–33 (2003); Jeffery, *supra* note 285, at 132–33; *see also* COLE, *supra* note 42, at 150–51 (highlighting the inadequacies of private property compared to public/state ownership in protecting endangered species).

288. Scholars have increasingly recognized the importance of local community ownership, as well as the role that such ownership and local community management can play in sustainable natural resource exploitation. *See, e.g.*. Julie A. Silva & Lila K. Khatiwada, *Transforming Conservation into Cash? Nature Tourism in Southern Africa*, 61 AFR. TODAY 17, 20–22 (2014); N. Leader-Williams, *Animal Conservation, Carbon and Sustainability*, 360 PHIL. TRANSACTIONS: MATHEMATICAL, PHYSICAL AND ENGINEERING SCI. 1787, 1791–92 (2002).

289. For a critical assessment of the limited effectiveness of the Endangered Species Act, see Jonathan H. Adler, *The Adverse Environmental Consequences of Uncompensated Land-Use Controls*, *in* PROPERTY RIGHTS: EMINENT DOMAIN AND REGULATORY TAKINGS RE-EXAMINED 187, 189–94 (Bruce L. Benson ed. 2010); Federico Cheever, *The Road to Recovery: A New Way of Thinking about the Endangered Species Act*, 23 ECOLOGY L.Q. 1, 10–33 (1996).

290. Smith, *supra* note 52, at 468–74.

property allows a broad range of viable uses (e.g., small-scale agricultural land in the pre-industrial era), granting ownership is likely to be a lower-cost method of coordinating potentially competing uses and mitigating wasteful rent dissipation.[291] Conversely, when the full effect of the use does not fall within a readily identifiable property boundary (as with air pollution, for example), or when economies of scale discourage discrete ownership (as with grazing grounds), control mechanisms must play a greater role.[292] Thus, achieving optimal management strategies—whether initially or in response to a changing resource utilization environment—will often mean changing both property ownership and control mechanisms.

Scholars have increasingly realized the importance of such "holistic" transition. In advocating greater and more precise exclusionary rules in favor of property owners over the low-altitude airspace above their land, Troy Rule has observed that when state legislatures enact statutes to create such property rights, the legislators "could easily structure new airspace rights statutes so as not to preclude the reasonable use of drones and other low-flying aircraft in certain emergency response settings . . . . [and] establish licensing processes for small drones and their operators comparable to existing requirements for automobile driving."[293] In a similar vein, Amy Sinden has argued against scholars' rigid dichotomization of privatization and government regulation, because it is almost impossible to create property rights that fully internalize all externalities or fully eliminate transaction costs. Sinden argues against viewing privatization as the conceptual opposite of government regulation because government regulation of the quantity and nature of resource use remains necessary even for purported "property rights" or "market" solutions to tragedy-of-the-commons problems.[294] Yet even in giving voice to the otherwise laudable recognition that property rights and regulation can (and should) go hand in hand, these studies fail to articulate one important assumption—that it is permissible and feasible for the state to institute or rearrange property rights in the first place. And as the above case study indicates, the degree of such permissibility and feasibility varies in accordance with the initial property rights arrangement.

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291. *See id.* at, 474–75. *See also* Lior Jacob Strahilevitz, *Information Asymmetries and the Rights to Exclude*, 104 MICH. L. REV. 1835, 1869–84 (2006) (discussing how information costs affect the resource owner's choice of the different exclusion strategies).

292. Butler, *supra* note 52, at 1693–94; Smith, *supra* note 52, at 474–75.

293. Rule, *supra* note 52, at 202–03.

294. *See generally* Sinden, *supra* note 34, at 546–66.

C. Caveats to State Ownership of Emerging Natural Resources

Given the above argument that state ownership facilitates both easier and more holistic transitions, this Article's ultimate conclusion should come as anything but a surprise: state ownership is the optimal form of property rights arrangement for emerging natural resources. In particular, the greater the uncertainty surrounding the long-term viability of the present patterns of resource utilization, the stronger the case for state ownership.

Still, three important caveats to this conclusion warrant further mention.

First, transition is particularly relevant only when there is uncertainty, whether uncertainty about the full consequences of the current form of resource utilization or uncertainty about the pattern of resource utilization in the near future. It becomes less compelling to factor in the possibility of transition if the resource-utilization pattern is stable and its consequences sufficiently well understood. In the case of atmospheric moisture, for example, if weather-modification technologies were to advance to a point where a weather modifier could effectively and cheaply divert atmospheric moisture to her land and deprive nearby lands of needed rain, there might be a strong case for a property rights arrangement incorporating a strong private veto right over any interference with atmospheric moisture one is "naturally" entitled to, particularly if advances in meteorological technology were to allow precise identification and tracking of atmospheric moisture. The flexibility of transition afforded by state ownership would be of little value at that stage.

Second, a distinction must be made between a) natural resources that humans have only recently harnessed on an industrial scale (such as atmospheric moisture, wind, sunlight, and underground pore space[295]); and b) natural resources that can be physically possessed with relative ease but only recently became of significant economic value (such as the numerous near-surface mineral ores that came into demand after technological breakthroughs in extraction[296] or utilization[297]). This Article's argument primarily

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295. *See supra* note 2 and accompanying text.

296. One example is oil sand, which has increasingly become economically viable thanks to more efficient extraction and refining, as well as high oil prices. *See* Clinton N. Westman, *Cautionary Tales: Making and Breaking Community in the Oil Sands Region*, 38 CANADIAN J. SOC. 211, 215–18 (2013); Atkins & MacFadyen, *supra* note 1, at 78–81. Another earlier example is aluminum; although aluminum ores were always in plentiful supply, the ores were of no economic significance before the development of low-cost electrochemical extraction methods. *See* James Ashby, *The Aluminum Legacy: The History of the Metal and its Role in Architecture*,

addresses the former, not the latter. The key distinction between these two types of emerging natural resources is that, with the latter, there normally already exists an established property rights regime (usually one based on land ownership) to be applied when the rising economic value of the resource begins to generate legal disputes. Conversely, the combination of a lack of economic significance and prior inability to possess or use the former type of resource—arguably the "true" emerging natural resource—meant that for the longest time, the discourse about its ownership (if at all) was firmly based only in scholarly and theoretical discussions, with hardly any practical implication or legal manifestation.[298] The distinction does not mean that transition is less relevant for the latter type of resource, however. Even though the substance in question has been readily possessable from time immemorial and is perfectly analogous to other conventional natural resources, new resource-utilization patterns and changing socioeconomic circumstances might well call for a different property rights regime.[299] Instead, the reason for the caveat is simply this: because there is

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15 CONSTRUCTION HIST. 79, 80–81 (1999); Colin J. Smithells, *On the Manufacture, Properties and Applications of Aluminium and its Alloys*, 98 J. ROYAL SOC'Y ARTS 822, 823–25 (1950).

297. Demand for rare earth mineral ores—used in a variety of novel electronics and green technologies—has dramatically increased over the past two decades. Robert F. Service, *Nations Move to Head Off Shortages of Rare Earths*, 327 SCIENCE 1596, 1596 (2010).

298. For example, Roman jurists' designation of air as *res communes* (that is, as a thing that cannot be legally owned and is subject to the right of enjoyment by everyone) was practically insignificant for a very long period of time, given the state of available technology prior to the Industrial Revolution . *See* Rose, *supra* note 106, at 93–94; BORKOWSKI, *supra* note 106, at 143. But with the advent of large-scale greenhouse gas emissions, one might argue that the absorption capacity of the Earth's atmosphere for greenhouse gases has been used to saturation by the industrialized North. *See* Winter, *supra* note 8, at 137; Jeremy Baskin, *The Impossible Necessity of Climate Justice?*, 10 MELB. J. INT'L L. 424, 430 (2009).

299. A good example is the renewed vigor of the public-trust doctrine in the U.S., which seeks to constrain the landowner from using the land or exploiting the resources on the land on the ground that certain resources, although formally owned by the landowner, are forever to be held in trust for present and future generations. *See* Michael C. Blumm & Aurora Paulsen, *The Public Trust in Wildlife*, 2013 UTAH L. REV. 1437, 1441–51 (2013); Klass, *supra* note 259, at 1027–32; Lazarus, *supra* note 259, at 633–56. Although ostensibly a common law doctrine traceable back to Roman law, the vastly expanded application of the doctrine in modern times runs counter to its historical roots. *See* James L. Huffman, *Speaking of Inconvenient Truths—A History of the Public Trust Doctrine*, 18 DUKE ENVTL. L. & POL'Y F. 1, 4–9 (2007). For a detailed historical deconstruction of the circumstances surrounding the landmark case of *Illinois Central Railroad Company v. Illinois*, 146 U.S. 387, 13 S.Ct. 110 (1892), which laid the precedential groundwork for the American public-trust doctrine, *see generally* Joseph D. Kearney & Thomas W. Merrill, *The Origins of American Public Trust Doctrine: What Really Happened in* Illinois Central, 71 U. CHI. L. REV. 799 (2004). Yet another example would be newly discovered antiquities, for which a hybrid solution of "possessory estate and future interest" may be preferable both to the conventional law of finders and to state ownership. Peter T. Wendel, *Protecting Newly Discovered Antiquities: Thinking Outside the "Fee Simple" Box*, 76 FORDHAM L. REV. 1015, 1051–62 (2007).

already an established property rights regime, declaring state ownership of the resource will itself be a transition, with all the accompanying challenges (particularly from inertia). Overcoming that inertia simply for the sake of an easier transition sometime in the future would not appear to be categorically more efficient than simply trying for a single transition in the future.[300]

Third, a certain level of institutional competence and good governance is required to realize the transition benefits of state property. Transitioning away from state property is a form of state management of natural resources, and as such is susceptible to well-recognized problems such as rent-seeking, corruption, and transaction costs.[301] For states where governance is so degraded that public management of natural resources is a mere façade for corruption, or where the state is utterly incapable of enforcing enacted laws and policies, any attempt at transition undertaken by a state would likely be misguided, ineffective, or both. That does not mean, however, that private property is normatively preferable in such circumstances. Private property—because it, too, is arguably a form of state institution[302]—would be similarly adversely affected by failures of governance. In this respect, Daniel Fitzpatrick has observed that the lack of governance capabilities in developing countries has resulted in a profound conundrum: formal private-property rights fail to completely exclude prior customary rights of the local community, while prior informal (and often quite efficient) governance fails to operate effectively when its norms run counter to formal law.[303] Similarly, governance failure will afflict transitions in the control mechanisms governing private property. A government that corruptly allocates state-owned assets to certain minority interest groups is just as likely to enact regulations to benefit those same interest groups.[304] Thus, this third caveat is simply a different way of

300. Still, there is one possible argument for an early transition to state ownership: transitioning away from private property is easier when there remains considerable uncertainty about the utilization patterns and economic value of the resource.

301. Patrick Wieland, *Going Beyond Panaceas: Escaping Mining Conflicts in Resource-Rich Countries Through Middle-Ground Policies*, 20 N.Y.U. ENVTL. L.J. 199, 252–53 (2013); Susan Rose-Ackerman & Sinéad Hunt, *Transparency and Business Advantage: The Impact of International Anti-Corruption Policies on the United States National Interest*, 67 N.Y.U. ANN. SURV. AM. L. 433, 459–62 (2012); COLE, *supra* note 42, at 38–40, 87–93; Morriss, Meiners & Dorchak, *supra* note 49, at 774.

302. Chen & Cui, *supra* note 283, at 46–47; *see* Rose, *supra* note 41, at 719 ("[W]e rely on governmental management of our preeminent system of resource management—private property—and we might view the entire private property regime as a 'public property' owned and managed by governmental bodies.").

303. Fitzpatrick, *supra* note 24, at 1010–21.

304. Chen & Cui, *supra* note 4, at 116.

saying that all property rights arrangements (including state property) in a failed or utterly corrupt state are normatively ambiguous, if not perilous.

V. READOPTING THE NEGLECTED TRIPLET

This case study has a broader message. Because state ownership is not inexorably correlated with more onerous regulatory controls, and because state property facilitates easier and more holistic transitions between property rights arrangements, state ownership deserves a thoroughgoing reexamination—both practical (how it actually operates across jurisdictions) and theoretical (whether it may be normatively desirable in more contexts than is commonly thought).

Despite being one of the three original ideal property types,[305] state property does not have much standing in the current literature. The risks of governance failures in the state management of resources have often been deployed as an argument against state ownership generally,[306] while at the same time Michael Heller and other scholars in the law-and-economics tradition have explicitly downplayed the theoretical value and practical significance of state-owned property.[307] In a certain sense, such neglect (and even disdain) is understandable. Given the backdrop of the Cold War, state property for a long time was (and to a certain extent, continues to be) overtly associated with socialism.[308] This association—in conjunction with the global demise of Soviet and other socialist regimes and with the widespread privatization that followed[309]—

305. Wyman, *supra* note 281, at 530; Heller, *supra* note 281, at 82–86; WALDRON, *supra* note 281, at 37–42.

306. *Compare, e.g.*, Wieland, *supra* note 301, at 253–55; Weinthal & Luong, *supra* note 66, at 38–46; *with* Morriss, Meiners & Dorchak, *supra* note 49, at 764–89 (arguing that a nondiscretionary, straightforward administrative system for allocating mineral rights to private entities helps mitigate the perils of public resources mismanagement); Rose, *supra* note 41, at 719–20 (discussing how the efficacy of state resource management is premised on critical assumptions such as ability of state to correctly identify market failure, expertise in exercising state power, lack of corruption).

307. *E.g.*, Heller, *supra* note 25, at xvi; BARZEL, *supra* note 25, at 71.

308. Heller, *supra* note 281, at 82–86; WALDRON, *supra* note 281, at 40–41.

309. *See* EDWARD W. WALKER, DISSOLUTION: SOVEREIGNTY AND THE BREAKUP OF THE SOVIET UNION 137-172 (2003) (detailing the events that led to the dissolution of the Soviet Union in 1991). For critical discussion of the subsequent market reforms, see Peter Rutland, *Mission Impossible? The IMF and the Failure of the Market Transition in Russia,* 25 REV. INT'L STUD. 183, 185–88, 190–91 (1999); Theodore P. Gerber & Michael Hout, *More Shock Than Therapy: Market Transition, Employment, and Income in Russia, 1991-1995*, 104 AM. J. SOC. 1, 35–38 (1998); Victor Nee & Rebecca Matthews, *Market Transition and Societal Transformation in Reforming State Socialism,* 22 ANN. REV. OF SOC. 401, 417–19 (1996).

provided ample ammunition for those who see state property as inherently inferior to private property, the trademark property rights regime of the victorious West.[310]

Nonetheless, the association of state property with socialism and the resulting scholarly neglect of state property are unfortunate, for at least two reasons. First, notwithstanding the end of the Cold War, state property remains an important property rights arrangement around the globe; constitutional declarations of state ownership over natural resources remain common.[311] More relevantly, and perhaps surprisingly, state property remains an important property rights arrangement in the United States. As shown in Part III, state ownership of atmospheric moisture has been explicitly declared by one-third of the states with regulatory regimes governing weather modification.[312] Given the lack of federal regulation in this area,[313] more states might adopt this approach when instituting their own regulatory regimes. Beyond the seemingly quirky nature of emerging natural resources such as atmospheric moisture, a large portion of real property—the classic paradigm of private property—in the U.S. is state-owned; the federal government alone owns nearly one-third of the total U.S. land mass.[314]

Second, and more importantly, the "taint" of socialism obscures the fact that, in both theory and practice, declaring a natural resource to be state property does not necessarily end in extensive and intrusive state intervention in the utilization of the resource. As the above case study shows, there is no clear correlation between state ownership of atmospheric moisture and the regulatory regime that accompanies it.[315] Close scrutiny of the actual effects of state ownership—or the absence of such effects—reveals that this seemingly counter-intuitive result should be unsurprising.[316] Tellingly, a close examination of the issue of relative ease of transitions reveals that state ownership of a particular resource will invariably involve forms of property rights transition. A state in managing its state-

310. *Cf.* Paul B. Stephan III, *The Fall—Understanding the Collapse of the Soviet System*, 29 SUFFOLK U. L. REV. 17, 19–30 (1995) (discussing and rebutting the widely perceived notion that the fall of the Soviet Union is evidence of the failure of Soviet communism).

311. *See, e.g.*, تونس دستور [Constitution of the Tunisian Republic], 2014, art. 13; XIAN FA [Constitution of the People's Republic of China], 2004, art. 9. *See* Alexandra R. Harrington, *Natural Integrity: the Relationship Between Anti-Corruption Laws and Natural Resource Protections in Latin America*, 17 CURRENTS INT'L TRADE L.J. 13, 19–20 (2009) (surveying the constitutional provisions on natural resources in Latin America countries).

312. *Supra* Part IV.B.

313. *Supra* Part IV.A.1.

314. Huber, *supra* note 69, at 993.

315. *Supra* Part IV.C.1.

316. *Supra* Part IV.C.3.

owned property might consciously choose property rights transition—including privatization—as a management strategy.[317]

Indeed, a whole host of methods can be utilized by the state to achieve de facto privatization or transitions to other forms of property rights even when there are powerful legal and ideological constraints inhibiting dissolution of formal state ownership. This dynamic was touched on above, in discussing the myriad private property interests that the U.S. federal government has created on lands that formally remain under full federal ownership.[318] Even in China, where the Socialist Constitution mandates state ownership of urban land,[319] a system of land-use rights has evolved that allows for possession, construction, and transfer of such land.[320] For all practical purposes, this system is equivalent to a leasehold regime like the one that prevails in the highly developed economies of Hong Kong[321] and Singapore.[322] Moreover, the Chinese system has prevented neither the emergence of a vibrant property market in urban land nor a florescence of commercial activity in China's urban centers.[323]

Thus, although aggressive management by government bureaucrats or regulators is anything but the optimal strategy for managing natural resources management in many scenarios, state property should not be scornfully or unceremoniously discarded

317. *Supra* Part V.A. In this regard, it is worth noting that the substantial land holdings of the U.S. federal government were acquired under the assumption that the land would be eventually sold or otherwise allocated to private entities. Huber, *supra* note 69, at 1022–26; *see* Joseph William Singer, *Sovereignty and Property*, 86 NW. U.L. REV. 1, 50–51 (1991).

318. *See supra* notes 282–283 and accompanying text.

319. XIAN FA [Constitution of the People's Republic of China] 2004, art. 10.

320. Art. 135–51, Property Law, *supra* note 278. *See* Donald Clarke, *China's Stealth Urban Land Revolution*, 62 AM. J. COMP. L. 323, 330 (2014) (discussing how the current Chinese property regime in the urban area "mimic[s] in many important respects a regime of private ownership of land"). For general discussion of the nature and status of land-use rights in China, see Wuquan faxue [PROPERTY RIGHTS JURISPRUDENCE] 206–55 (Zhang Yihua & Luo Xiaojing eds., 2010).

321. Clarke, *supra* note 320, at 345–49; Lawrence W. C. Lai, *A Model of Planning by Contract: Integrating Comprehensive State Planning, Freedom of Contract, Public Participation and Fidelity*, 81 TOWN PLANNING REV. 647, 663–67 (2010); Berty F.C. Hsu, *Asset Quality in HKSAR's Real Estate Markets: A Public Policy and Legal Analysis*, 19 UCLA PAC. BASIN L.J. 263, 264–66 (2002).

322. Sock-Yong Phang, *Economic Development and the Distribution of Land Rents in Singapore: A Georgist Implementation*, 55 AM. J. ECON. & SOC. 489, 491–96 (1996); N. KHUBLALL, COMPULSORY LAND ACQUISITION SINGAPORE AND MALAYSIA 4 (2nd ed. 1994)

323. *See* Christopher K. Hsee, Jean-Pierre Dubé & Yan Zhang, *The Prominence Effect in Shanghai Apartment Prices*, 45 J. MARKETING RES. 133, 133 (2008); Shitong Qiao, *Small Property, Big Market: A Focal Point Explanation*, 63 AM. J. COMP. L. 197, 204–11 (2015) (discussing the booming urban real estate market in China, both in urban land, where such a market is formally allowed, and rural land, where there is more ambiguity about the legality of transactions in land).

from normative and descriptive discussions of property rights. Continuous and active state intervention is but one approach that a state may adopt for managing state property. Indeed, as one previous comparative case study revealed, the emphasis on safeguarding publicly-owned resources led Singapore to adopt market- and property-based solutions to address traffic congestion; these solutions have achieved superior outcomes in terms of efficiency and redistribution.[324] A better appreciation of the practical operation and possible merits of state property, in tandem with continued research in the vein of the present Article, will open up further vistas in the exploration of optimal property rights.

CONCLUSION

Over the past fifty years, the vastly accelerated pace of technological advance has fueled a relentless search for new ways to interact with, and influence, our natural environment. As we confront difficult decisions about the legal status and normative design of property rights to ever-increasing categories of emerging natural resources, due consideration must be given to how the ease and nature of future transitions may be affected by the initial allocation of property rights. This case study on the ownership of atmospheric moisture in the United States has revealed that state ownership can promote surprising regulatory flexibility, in both theory and practice. More broadly, the case study suggests that, stripped of its understandable but undeserved socialist baggage, state property deserves to play a larger role in the ongoing scholarly conversation.

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324. Chen & Cui, *supra* note 283, at 5–19; *see also* Jianlin Chen, *Curbing Rent-Seeking and Inefficiency with Broad Takings Powers and Undercompensation: The Case of Singapore from a Givings Perspective*, 19 PAC. RIM L. & POL'Y J. 1 (2010) (explaining how a broad conception of public-owned resources, one that encompasses the derivative bestowal of benefits, has coupled with the near obsession about preventing uncompensated transfer to private entities, to help promote government efficiency and reduce corruption even in the absence of strong legal protections of private-property rights).