

Annual Review of Resource Economics
Emerging Issues in
Decentralized Resource
Governance: Environmental
Federalism, Spillovers, and
Linked Socio-Ecological
Systems

William Shobe

Frank Batten School of Leadership and Public Policy, University of Virginia, Charlottesville,
Virginia 22903, USA; email: shobe@virginia.edu

Annu. Rev. Resour. Econ. 2020. 12:259–79

First published as a Review in Advance on
April 27, 2020

The *Annual Review of Resource Economics* is online at
resource.annualreviews.org

<https://doi.org/10.1146/annurev-resource-110319-114535>

Copyright © 2020 by Annual Reviews.
All rights reserved

JEL codes: D7, D73, H0, H7, Q5, Q57

Keywords

environmental federalism, socio-ecological systems, laboratory federalism, polycentric governance, complex adaptive systems

Abstract

Spillovers among jurisdictions are ubiquitous and likely to increase with increasing population and consumption, so the centralization or decentralization of environmental governance is of pressing concern in a world of tightly linked socio-ecological systems. Spillovers play a key role in federalism analysis because they tend to reduce benefits from decentralization. Laboratory federalism, a common rationale for decentralization, has not proven successful as a model of local policy innovation. Given a national policy toward a public good, differences in preferences across jurisdictions may push national policy toward a quantity instrument rather than a tax instrument. Finally, the lack of interaction between environmental federalism analysis and studies of adaptive governance and linked complex adaptive systems leaves both literatures incomplete. The increasing urgency of global sustainability issues argues for linking insights from environmental federalism with the literature on linked socio-ecological complex adaptive systems.

**ANNUAL
REVIEWS CONNECT**

www.annualreviews.org

- Download figures
- Navigate cited references
- Keyword search
- Explore related articles
- Share via email or social media

INTRODUCTION

The closed economy of the future might similarly be called the “spaceman” economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything. (Boulding 1966, p. 8)

Federalism as an academic discipline studies how multilevel political jurisdictions interact, both vertically and horizontally. Environmental federalism shifts and expands the focus by concentrating on environmental goods, which are related to ecosystem services. This shift necessarily expands the inquiry to include investigation of how ecosystem services respond to changes in resource management by human governance institutions. Fiscal federalism focuses on tax and expenditure policies for providing potentially underprovided goods such as education, transportation, public safety, and local environmental goods. Environmental federalism tends to focus on valuable, but incompletely owned, natural resources such as air, water, wildlife, and natural aesthetics.

Governance institutions are necessarily embedded in the nested structure of political jurisdictions, from international treaty organizations to national governments to provinces to towns. I emphasize the political nature of these jurisdictions because political decision making is an inescapable property of human institutions. In turn, human institutions and their web of political and individual decisions are necessarily linked to the system of ecosystem services that supports human survival and ability to thrive.

Human and ecological systems are intrinsically linked, complex adaptive systems (Arrow et al. 2014, Carpenter et al. 2012). Environmental factors have always played a role in the evolution of human institutions, including the structure of political governance, and there is every reason to believe that the increasing human population will increase the intensity of the interaction among these systems (Diamond 1997). While both systems are adaptive, human social systems are distinct, in that humans can reflect on the structure of their institutions and assess how these may affect future outcomes. Within the constraints of political decision making, humans may actively choose among various pathways.

A growing literature on adaptability and resiliency of human institutions has begun to explore the links between variations in ecosystems and responses by human institutions (Folke et al. 2005). Much of this literature explores the nature of local responses to ecological changes to understand how different organization arrangements affect institutional responsiveness. There are numerous links between this adaptation literature and the explicitly economic treatment of local and polycentric governance of common pool resources (Folke et al. 2005, Ostrom 1990).

Human responses to ecosystem changes must always occur through political and economic institutions (Agrawal 2003b). As concerns mount over the sustainability of current patterns of resource use and ecological services (Centeno et al. 2015), it is increasingly important to forge a link between our understanding of environmental change and our understanding of how human institutions respond, not only at the local level, but through the hierarchical chain of nested jurisdictions that characterize all human governance institutions. We do not know what adaptive policy responses are feasible or are likely to occur unless we understand the existing structure of decision and control along with how we might adjust existing institutions to improve their adaptability (McCann 2013).

A jurisdiction is a geographic extent over which some set of resources are managed by a public governance institution, with a generic output that we might call governance, the institutional framework for allocation of resources (North 1990). Jurisdictions have a set of characteristics:

- Physical boundaries
- Culture: ethnic history, social capital, uniformity of preferences

- Institutions: legal system, public decision making, education
- Nestedness: level in relation to other jurisdictions
- Local resource attributes

Environmental resources do not generally coincide with jurisdictional boundaries, and the various ecosystem services relevant to a locality, such as air, water, and wildlife, interact in complex ways that span multiple jurisdictions (Wilson 2003). Another important characteristic of localities is that, whatever their level, they tend to encompass communities sharing some common identity and a variety of social ties.

The central question in federalism studies is about the consequences and advisability of assigning various governance tasks to national governments or to their nested, relatively fixed, general-purpose governance subjurisdictions such as states, provinces, counties, and cities. There are also many special-function subjurisdictions¹ that may not nest neatly within the existing general-purpose jurisdictions. A few common examples include multicomunity planning districts, regional waste management authorities, interstate pollution control compacts, and watershed management compacts.

There is an essential tension between the merits of decentralized and centralized assignment of governance responsibilities (Treisman 2007). Small jurisdictions are thought to more closely match local preferences and to have more immediate connections between revenues and expenditures. Larger jurisdictions, on the other hand, can help solve problems of scope, scale, and spillovers (Agrawal 2003a, Ahmad & Brosio 2008). Treisman (2007) provides a very thorough catalog and analysis of the various issues and the available empirical evidence for and against various levels of centralization and decentralization. He concludes that, owing to the many conflicting influences, there is little in the way of general guidance from the literature about the appropriate assignment of governance functions to particular jurisdiction levels.

In what follows, I elaborate on two key themes. First, some of the perceived advantages of decentralized authority may not hold up well on examining the specific circumstances of given cases. This is especially true in the case of spillovers among jurisdictions. Except under strong conditions on transaction costs, environmental spillovers weaken the case for decentralization of authority. Second, the growing literature on complex, adaptive socio-ecological systems adds an important dimension to the traditional environmental federalism approach. Increased population and environmental pressures will tend to increase the environmental spillovers among jurisdictions, which would seem to argue for less decentralization. But there are cases where the resilience of complex adaptive systems is improved by modularization (or decentralization) of adaptive units. As yet, we have little research to help resolve this tension. Improving the integration of the environmental federalism and complex adaptive systems models is an important area for future research.

In the next section, I focus on a specific piece of the puzzle: the question of policy trade-offs in the presence of spillovers of public goods between jurisdictions, in particular, when there are large differences in the valuation of those goods by the voters in the jurisdictions.² Throughout this review, the term public good is taken to mean any valued resource that is nonrival and nonexcludable. For my purposes here, a public nuisance (or public bad) can be seen as simply a public good with a negative value.

¹Berry (2009) provides an analysis of the effects of multilevel governments.

²For reviews of the empirical literature in environmental federalism, see Millimet (2014) and Dijkstra & Fredriksson (2010).

SPILLOVERS

Services in a Single Jurisdiction

To explore the question of spillovers between jurisdictions, we start with the public goods provision problem in a single, lower-level jurisdiction. Local residents have preferences concerning the level of supply of a purely local public good and have the opportunity to vote for politicians offering to provide various levels of that good. If the community is unanimous and well informed (Boffa et al. 2016) about the policy, then it is likely that local decisions over the supply of the public good will closely match those of all voters. If there is a distribution of opinion in the community, then we assume for simplicity that preferences are single peaked, and the voting mechanism pushes the outcome toward the preferences of the median voter.³

Even with single-peaked preferences, where the median voter's preferences set local policy, the wider the range of preferences of all voters, the further the actual policy decision will be from the preferences for the level of public goods of many individual residents. For a pure public good, it is not feasible to differentiate the supply of the good among residents. If it were possible, then the locality could better match preferences by targeting different levels of good to different voters, but such differentiation may be quite costly (Berry 2009).

Uniform preferences toward the public good within a jurisdiction will lead to a close matching of policy to preferences. The local politician responds to the median voter, who is similar to all the other voters. Conversely, the greater the differences, the further the preferences of many voters will be from the median voter's preferences.

One key lesson from the federalism literature is that the possibility of closely matching tax payments to the value of benefits received, benefits taxation, is an important advantage of having jurisdictions where everyone has similar preferences toward public goods (Fischel 2001, Nechyba 2001, Zodrow 2001).⁴ If preferences are not relatively uniform, then it is less likely that a locality can use benefits financing. From a politician's point of view, having voters who all share similar preferences for public goods makes providing the desired level of public services consistent with the desire for reelection (Lockwood 2008). More diffuse preferences make it more likely that the disaffected (whose costs and benefits do not match) might move elsewhere or work to defeat the incumbent.

Spillovers Among Jurisdictions

Next we consider the case of public goods spillovers among jurisdictions. Not only are spillovers ubiquitous, but we have both persuasive theory and considerable evidence that localities place a lower value on effects in other jurisdictions than on local effects (Fell & Kaffine 2014, Lipscomb & Mobarak 2016, Sigman 2002). This unsurprising result implies that, in the presence of spillovers, matching local policies to local preferences will result in underinvestment in public goods spanning many jurisdictions.⁵

One possible response to the presence of spillovers is to form a new subjurisdiction that encompasses the spillover. Berry (2009) studied 13,500 school districts and 35,000 nonschool special districts in the United States.⁶ Nonschool special district services include a wide variety

³This assumption is somewhat restrictive but quite satisfactory for our purposes here (Inman 1985).

⁴Bird & Slack (2014) refer to this link between local choice and local financial consequences as a Wicksellian connection.

⁵Even this seemingly common-sense result has its exceptions (Koethenbuenger 2008).

⁶Taking this idea to its logical extreme, Eichenberger & Frey (2008) propose a free-wheeling dynamic system of "functional, overlapping and competing jurisdictions" for providing very specific individual public goods and services.

of services covering water supply, waste, transportation, wildlife, parks, and many more. Berry provides a comprehensive evaluation of how the creation of new, intermediate jurisdictions affects governance outcomes. The conclusions are not encouraging. On average, new jurisdictions have low levels of political participation and responsiveness along with high levels of corruption. They provide targets for rent seeking by concentrated interests and, as a result, often have excessive levels of expenditures.

The distribution of preferences over public goods among voters plays a pivotal role in determining the consequences of a given level of centralization. If local preferences are very different among the jurisdictions involved, then at the encompassing level, while spillovers are internalized, aggregate preferences will generally be less concentrated. Spillovers tend to work against any advantages of decentralization (Sigman 2005), but larger jurisdictions generally imply a wider array of value placed by citizens on a given public good. This, in turn, may result in higher rent-seeking costs (Cheikbossian 2008). In each case, we need to understand how spillovers and divergent preferences for public goods will be balanced against each other.⁷

Given the persistent belief that decentralization has intrinsic advantages, then an appealing characterization of how an optimizing social planner might respond to spillovers suggests assigning the policy responsibility for spillovers to the lowest jurisdiction that encompasses the jurisdictions affected by the spillovers (Oates 2004).⁸ The planner first chooses a jurisdictional extent, either a higher-level existing jurisdiction or a special-purpose jurisdiction established for this purpose, and then establishes an efficient regulatory regime to supply public goods at the encompassing level (Dalmazzone 2008).

One cost of raising the jurisdictional level is the loss in preference matching due to a wider array of preferences contained in a single, larger jurisdiction. The case for matching policy extent to the higher level of jurisdiction is strongest when the spillover affects everyone in each of the subjurisdictions and there are similar preferences across the jurisdictions.⁹ In this case, the aggregation of preferences to the higher level does not change the median voter or that voter's preference distance from other voters (Rubinfeld 1985).

If preferences across the member jurisdictions differ substantially, then the case for an encompassing jurisdiction is less clear. As an example, suppose there are two jurisdictions: High Town (H) and Low Town (L). These jurisdictions share a uniformly distributed public bad (nonrival, nonexcludable). The people of H all place a very high value on reducing emissions (E), while the people of L place a low value on reducing E. To maximize social welfare, a social planner would aggregate the marginal willingness-to-pay (MWTP) schedule across all citizens of L and H and would set the level of public good so that MWTP would equal the marginal cost. This optimal level of E is what the citizens of L and H would choose if transaction costs were zero and they could arrange to contract with each other over E and arrange side payments.¹⁰

⁷Ventura (2019) shows that, for uniformly distributed public goods where there are spillovers between jurisdictions, the relative magnitudes of the spillover value and the local value of the good should determine the assignment of responsibility for providing the good. If the spillover value is greater, then use the higher jurisdiction; if the local value is greater, use the lower jurisdiction. Ventura does not suggest what authority might make this assignment.

⁸Other options include having the higher jurisdiction use payments and charges to give incentive for a lower jurisdiction to take spillovers into account. I do not discuss this possibility except to note that it is subject to many of the same political limitations as the choice of centralized or decentralized governance.

⁹Of course, in the case of zero contracting costs, the jurisdictions would negotiate to form a special, joint district for internalizing the spillover (Libecap 2014). That said, the transaction costs and strategic political delegation appear to present formidable obstacles (Eaton & Kostka 2018).

¹⁰In the case of only two jurisdictions, we might observe the governments of H and L engaging in negotiations over E (Libecap 1989), although even between a small number of jurisdictions, the transaction costs of

Leaving aside the social planner's problem and returning to the likely political choices we expect to observe, I consider two cases: one where the jurisdictions are forced to combine and one where they may choose whether to do so.

What would we expect to observe if H and L were forced into a combined single jurisdiction? It is now much less likely that preferences are single peaked, so the outcome will depend on specific features of the political processes in L and H.¹¹ The larger jurisdiction will be more likely to get its way, and there is no reason a priori to expect the outcome to be efficient. It is less likely that we can depend on a median voter driving outcomes toward efficiency (Inman 1985).

If, instead of being forced to combine, each jurisdiction voted on whether to join an encompassing jurisdiction, then the smaller district could never improve their outcome by voting "yes," since, as part of a larger district, they would never get their way. Lorz & Willmann (2005) argue that, if the level of (de)centralization is endogenous, then there is reason to expect that the voters in the subjurisdictions will choose a level of centralization that is suboptimally low, that is, too much decentralization.

This suggests that moving spillovers into an encompassing jurisdiction cannot be expected, by itself, to improve the outcome by internalizing spillovers, nor will offering the jurisdictions a chance to combine into one encompassing jurisdiction. Even if the jurisdictions chose to combine, one cannot conclude that the new jurisdiction, comprising two very different subjurisdictions, would move closer to the optimal level of the public good. We cannot assume that, if we raise the jurisdiction level, political processes at the higher-level jurisdiction will set policy closer to the optimal level.¹²

So far, we have considered only goods (or bads) that span all subjurisdictions of the encompassing jurisdiction. The logic of pushing the jurisdiction assignment up a level is weakened if the nature of the spillover is such that it does not affect an entire encompassing jurisdiction, covering only part of the geography and its associated population. For example, suppose there is a public good affecting a small region in a larger country. Then the welfare loss at the national level may be small, as would the payoff to national politicians for addressing the problem. We cannot depend on the median voter in the higher jurisdiction to pick an optimal policy, because there may be little perceived gain or loss to the median voter from the regional spillover in just a few of many subjurisdictions. This is especially true if the higher jurisdiction is limited to uniform policies across its lower jurisdictions, as might be the case if there are uninformed voters (Boffa et al. 2016). The loss to preference matching from raising the problem to a higher jurisdiction may be quite large and may even be larger than the benefit from internalizing spillovers (Cheikbossian 2008, Ventura 2019).

Suppose that national policy makers need to fashion a new district from pieces of lower jurisdictions in order to match the extent of the jurisdiction to the extent of the spillover. Then there will be objections from jurisdictions being asked to cede sovereignty over some valuable characteristic of geography otherwise under their control. And political delegation by voters to political representatives may result in inefficient levels of centralization (Lorz & Willmann 2005).

Furthermore, existing levels of government serve as a locus of administration for taxation, expenditures, and other policies. These functions probably exhibit substantial economies of scale

negotiating even the level of E, much less a set of side payments, sometimes appear considerable (Eaton & Kostka 2018). In a world with many H and L jurisdictions, the likelihood of a negotiated settlement becomes much less likely (Libecap 2014). It is also true that these jurisdictions may need to rely on some agency that could enforce the contract, probably a higher-level jurisdiction.

¹¹ Boffa et al. (2016) show that the outcome also depends on the share of well-informed voters versus those less well informed.

¹² There may be other coalition formation processes, but I stick with the median voter for all of my examples.

and scope. Breaking out some subset of functions related to each significant spillover would likely be quite costly compared to managing the spillover within the existing management framework (Treisman 2007). Political control of any governance institution entails costs in voter attention and, hence, in the realization of effective political control over institutions (Berry 2009).

Local jurisdictions often form the locus of social identity, preferences, and behavioral norms (Ostrom 1990). Uniform local preferences may lower the cost of establishing and maintaining robust local resource governance institutions. Changing the locus of decision away from established cultural expectations may reduce the effectiveness of institutions.¹³

The Chesapeake Bay watershed in the eastern United States provides an instructive example. This watershed comprises parts of Maryland, Pennsylvania, and Virginia. A major ecological and economic resource on the east coast, the Bay has suffered serious pollution damages and overextraction of valuable seafood resources. In 1980, in response to a large study by the US Environmental Protection Agency (EPA), the three states formed a commission to facilitate cooperation to protect Bay resources. Aside from modest federal grants, there was, for nearly 30 years, little appetite on the part of either the states or the national government to form a binding jurisdiction under national authority for resolving Bay management problems. Rather, the states have acted independently with some level of voluntary coordination through the commission.

Progress has been halting and painfully slow. Funding has been erratic, and state legislation has lacked coordination. In 2007, in response to the failure of the Bay states to achieve substantial progress in reducing pollution entering the Bay, the EPA started the process of establishing nationally enforceable limits, under the national Clean Water Act, on nitrogen, phosphorous, and sediment entering Bay tributaries. In 2010, the states agreed to effluent budgets for Bay tributaries. The states and the EPA agreed to a compliance schedule and accountability framework. At the 2017 checkpoint, the states had achieved their goal for phosphorous and sediment but not for nitrogen. As of this writing in 2020, it is not clear whether the US government still intends to enforce effluent limits and whether the Bay states will push ahead with the agreed to 2010 limits.

Spillovers and Local Policy Flexibility

I turn now to consider the flexibility that local jurisdictions have in responding to environmental policies established at the national level. Local jurisdiction reactions to national policies may undermine the efficiency of the national policy. For example, the cost-minimizing approach to controlling a nationally uniform public bad, such as air emissions, can be achieved, in principle, by setting a uniform fee on the emissions or by setting the commensurate cap on emissions and allowing market activity to set the emission price. In federal jurisdictions, localities will respond to the national policy in ways that may substantially shift the results away from the level chosen by the national policy (Burtraw & Shobe 2009, Burtraw & Woerman 2013, Goulder & Stavins 2011, Shobe & Burtraw 2012).

In the previous section, I addressed the question of the appropriate size of jurisdictions in the presence of spillovers. The answer turned, in large part, on the dispersion of public goods preferences across jurisdictions. The greater the preference dispersion among localities, the greater the trade-off between centralization to internalize the spillover and decentralization to improve the matching of preferences to policies. In this section, I examine the choices localities might make in response to the establishment of the national policy.

¹³ Balanced against this benefit of local cultural cohesion is the possibility of the capture of governance institutions by local elites. But this topic lays well outside the scope of this review.

Assuming that an emission limit for a national public bad will be set at the national level, subnational jurisdictions must choose their best response given their own circumstances. Suppose, for example, that the national government establishes a national price on CO₂ emissions. Our usual way of thinking about establishing the national policy is that we use the given characteristics of individuals and firms to set the national price on emissions. In countries with a federal structure, the actual decision will be made by political delegates from subnational jurisdictions to the national legislature. The political decision and the social planner optimum may be quite different. However the decision is made at the national level, the *local* marginal value of reducing CO₂ emissions and *local* marginal costs of abatement will be distributed around the national price chosen. Localities will make their best response to whatever policy is chosen at the national level (Williams 2012).¹⁴ An analysis of potential local responses may, in turn, determine the best national policy.

Given that the national government is able to establish an efficient national emissions pricing policy, there would seem to be little room for national policy makers accommodating regional preferences in achieving the national emission goal. But each subnational jurisdiction perceives different costs and benefits and responds to the national policy with its own choice¹⁵ of local tax, expenditure, or regulatory policies. Localities that find the national emissions pricing policy particularly costly can shift tax burdens to nonemitting sectors, reduce local regulatory costs, or increase incentives for the favored industry. In the case of a CO₂ price, localities heavily invested in the production of fossil fuels may take steps to protect local industry from the full force of the national policy. This changes the exposure of local actors to the national emissions pricing policies, moves the economy away from the national, least-cost reductions and may, as we discuss below, either increase or decrease emissions relative to the national target. This is true at each level of governance.

For example, in the United States, counties and cities have long had the power to use zoning to regulate patterns of land use. Local landowners are known to vote for using the zoning power to protect property values. A national policy that encourages changes in land settlement patterns may threaten property values for some share of local constituents who will vote for policies that blunt the effects of the national policy on property values.¹⁶

An additional side effect of the zoning power is to reduce the opportunities for migration as production patterns shift in response to the national policy. Migration will occur in response to changing employment opportunities as the economy adapts to both the effects of emissions that do occur and the policies designed to reduce them. Frictions in migration raise the cost of achieving a given level of emission reductions. Desmet & Rossi-Hansberg (2015) estimated that the optimal, unrestricted relocation of people and production in response to rising temperatures requires the large-scale relocation of people toward cooler latitudes in a span of less than 200 years. Rapid relocations of people on this order of magnitude are generally associated with deep institutional dysfunction and armed conflict. But the frictions imposed by restricting migration make the consequences of climate warming more costly in other ways.

Jurisdictions with extractive industries or greenhouse gas (GHG)-intensive production can work to protect those industries. Those with stronger preferences for reducing emissions will

¹⁴See Burtraw & Shobe (2008). If preferences toward the national policy were uniformly distributed across subnational jurisdictions, this would not be an issue. The median voter in every jurisdiction would want the same policy as the country.

¹⁵The policy flexibility at the local level varies widely across counties depending on the degree of policy independence available to local jurisdictions.

¹⁶Local opposition to the siting of wind and solar facilities illustrates the many frictions that may slow the economy's response to national prices.

implement policies that would reduce emission by more than would occur due to the price alone. How effective the various local responses are at either boosting local outcomes or changing costs and emissions depends on whether the national policy uses a tax or quantity instrument. Either way, local policies raise the cost of achieving national emission reductions. If the added costs fall on the local jurisdiction, then there is less concern than there would be if the added costs fall on other jurisdictions.

Local Responses to National Emission Pricing Policies

Local responses to national policies will have different results depending on whether the national government uses a price or quantity instrument for reducing emissions (Goulder & Stavins 2011, Williams 2012). Local policy responses will increase the risk of higher emissions under a national emission price compared to that under an emission cap.

I return to the example of two localities with locally uniform preferences for reducing national emissions: H (a green locality with a high value of reducing emissions) and L (a locality with emission-intensive industries). Each locality would consider its best policy response to the national policy, trying to bring the local outcome closer to its own preferences and costs.

Starting with a national trading program, how would H and L respond with local policies? L prefers less control of national emissions but does not have any ability to raise national emissions above the cap. L may already have had a policy of supporting high-emitting firms. If high emitters will tend to lose value or relocate due to the cap, L may spend local money trying to keep the local high emitters afloat.¹⁷ This will not change aggregate emissions because increased emissions in L will require reduced emissions elsewhere, but it will tend to raise equilibrium allowance prices above what would have otherwise occurred. Additional local spending to attract the emitters is not of national concern, but a higher emission price on everyone else might be.

H, on the other hand, wants fewer emissions than the national cap and has a willingness to pay for extra reductions. H will want to contribute to lower emissions, but no additional effort at emission reduction can lower the cap.¹⁸ Any local reductions will be matched by equal increases elsewhere as long as the cap is binding (Burtraw & Shobe 2009). This effect has been referred to as 100% leakage of emissions to other local jurisdictions (Goulder & Stavins 2011). But it is not clear why this leakage should be policy relevant to the national government. Assuming that the national cap was set optimally, there is no obvious reason why localities should be empowered to raise or lower the national cap.

Suppose H feels that reduced local emissions will make it an attractive locality to potential migrants.¹⁹ If H does reduce emissions beyond what is profitable at the current allowance price, this imposes an additional local cost but no overall emission reduction.²⁰ It also reduces somewhat the equilibrium price of allowances below the true social marginal cost of emissions because the aggregate demand for allowances has been lowered. Thus, not only has the locality not reduced

¹⁷Although the high emitters will probably become relatively less attractive as economic targets due to the national emission cap.

¹⁸I am ignoring for the moment the possibility of the cap being close to nonbinding, in which case reducing local emissions might result in the retirement of unused allowances, a reduction in the cap itself.

¹⁹There may be co-benefits from reduction in other emissions, good publicity for the local jurisdiction, or just public spiritedness. It may not be obvious which motivation is at work.

²⁰The locality's increased costs are not a national concern. Localities are under no obligation to minimize their own costs. Providing local emission reductions may have value to local citizens independent of the contribution to overall emissions.

emissions, it has also reduced the national equilibrium price of allowances. If H decides not to directly reduce emissions, it can purchase and retire allowances at the market price. This would raise the price above the nationally optimal price. These effects on the national emission price shift national incentives for investing in new emission reduction technologies.

We do not yet have a clear policy rationale for the national government intervening to prevent a locality from spending local money on local emission reductions or spending to keep some of the emissions locally. It is also not clear what the national government's best response is to locality policies that move the aggregate price of allowances away from the estimated social marginal value of allowances. Is there a reason why we should treat the voluntary contributions to reduced spillovers differently from local efforts to retain economic activity? Both of these policies move allowance prices away from their social optimum but in opposite directions.

Given the absence of an adequate policy response to the current global climate crisis, there may be a tendency to treat voluntary contributions to reducing emissions more favorably than efforts to prop up emission-intensive local employers. But a general assertion of an asymmetry in our treatment of these two local responses to national policy needs a more general justification. The 100% leakage of emission reductions from a locality under a national cap is symmetric with the 100% negative emission leakage implied by local economic development efforts. And preemption of all such local efforts is not possible.

Next we turn to the response H and L might make to an emission tax. As you might expect, while local actions under a cap increase price variance, local options under a price instrument increase quantity variance. Again, L prefers less control, presumably because emitting activities are valuable to L voters. What might L do? L may use local tax instruments or expenditures to reduce the post-policy tax incidence on emitters. Such a move would increase emissions in L relative to emissions under the national tax alone. National emissions will be higher by that amount.

H wants fewer emissions and may impose some complementary policy reducing emissions beyond what would occur under the tax alone. These high-cost emission reductions raise the total national cost of compliance but only through the local effect on H, so although emissions are lower than the optimal amount for the nation, the costs are concentrated on H itself, although there would be some loss in revenues earned by the national emission tax.

The net effect on emissions depends on the distribution of willingness to pay in L and H. As the policy becomes more stringent and the tax rises, the number of L jurisdictions may tend to grow relative to the number of H jurisdictions. The local response to the tax would result in a net increase in emissions relative to the national optimum, and this effect would grow as the national policy became more stringent.

The higher-level jurisdiction may seek to preempt these actions by lower jurisdictions. Because lower jurisdictions may have many policy levers, preemption of local efforts can be quite challenging. Localities that have taxing, spending, and regulatory authority may be able to substitute one policy lever for another to change the effect of national preemption (Weiland 2000).

The potential for upper-level jurisdiction control over lower jurisdiction actions is also constrained by the possibility of secession. Sorens (2016) and Treisman (2004) argue that secession risk encourages increased grants to localities (fiscal appeasement) but not a parallel grant of taxing and regulatory authority. Granting local governmental autonomy may facilitate secession, a possibility that politicians at higher governance levels wish to avoid. The possibility of secession results in greater centralization of taxing and regulatory authority. Rather than observing preemption, we would tend to observe passive preemption: a more unitary governance structure but with larger fiscal payouts to regions most likely to secede.

Laboratory Federalism

Local policy experimentation, or laboratory federalism, has long been thought to be a key advantage of governance decentralization (Treisman 2007). The theoretical and empirical case for the value of laboratory federalism has never been as strong as its superficial intuitive appeal. I argue here that, in the presence of interjurisdictional spillovers, the case for significant advantages from decentralized policy experimentation is weaker still. And, as we have already seen, not all (or even most) state policies are directed at increasing national welfare. State policy experimentation can work for good or ill. It is also possible that some policy initiatives may serve as a form of policy signaling among localities, in which case we need to rethink our underlying model of state-level policy development.

The laboratory federalism idea draws an analogy between the information aggregation functions of markets and the similar function that competition among jurisdictions might serve. According to this view, competitive policy entrepreneurs in local jurisdictions have incentive to engage in policy experimentation to discover new, more effective policy approaches. Once these have been discovered, competition among jurisdictions provides strong incentive for the adoption by other jurisdictions of successful new policy technologies. Localities that do not use the most effective policy instruments will fall behind, leaving local politicians vulnerable to losing their bid for reelection.

Support for the benefits of decentralized experimentation rests on two key pillars: experimentation and competition. These are often accompanied by an implicit assumption that experimentation serves a positive policy goal. While there are anecdotal accounts of policy innovation and diffusion among localities (Volden 1996), considerable theoretical and empirical investigation has offered reason to be skeptical that, other things equal, policy decentralization enhances policy innovation (Cai & Treisman 2009, Rose-Ackerman 1980, Strumpf 2002, Volden et al. 2008).

Probably the greatest weakness of the local policy experimentation model is in the use of the word “experiment.” To be informative, in the sense of connecting future actions with future outcomes, an experiment requires three design elements: hypothesis design, error-control design, and sampling design (Hinkelman & Kempthorne 1994). The less attention paid to each element of experimental design, the less informative the experiment. Local policy experiments generally attend only to the treatment or hypothesis. Error control (control over observation) is particularly problematic, since we cannot expect that the same policy is implemented in different jurisdictions in the same way and outcomes are measured the same way. There is little evidence that different jurisdictions agree on details of implementation and measurement protocols for their respective “policy experiments.”

Take, for example, the model of policy experiments in Volden et al. (2008). Each of the n policy makers chooses a policy, which is assumed to be fully observable. Policy makers have priors about outcomes that they update based on the k trials they observe of the policy among the n localities. But local policy experiments can be expected to have many, large, unmeasured differences in law, institutions, implementation, timing, etc. These differences will depend on unobserved properties of localities related to the hypothesis about whether the particular policy works or not. Consequently, the information contained in any one policy maker’s experiment is essentially nil. It takes many localities trying the same policy to have any hope at all of controlling for nonrandom assignment and self-selection into treatment and control groups. Furthermore, policy entrepreneurs come in political flavors and will tend to choose from a correlated menu of policy choices. Even with a large number of jurisdictions, the inference will be weak and subject to serious bias.

Volden et al. (2008) make a key point about laboratory federalism that, from the outside observer’s point of view, much of what appears to be policy learning is consistent with each individual

jurisdiction engaging in myopic policy implementation that does not depend on the outcome of local policy experiments. Myopic policy choice does not match the narrative of laboratory federalism.

A well-known difficulty with the policy experimentation model is the incentive for free-riding by other jurisdictions (Rose-Ackerman 1980, Strumpf 2002). The same goes for policy entrepreneurs. Even if one is in a position to tell when a policy is or is not successful (often a dubious proposition), it is difficult to capture a substantial share of the benefits of successful policy entrepreneurship. Free-riding is only made worse by the difficulty in demonstrating that a policy was successful.

The policy learning model in Volden et al. (2008) demonstrates clearly that this free-riding incentive limits the potential value of local policy experimentation. Because there is so little information in a single jurisdiction's actions, learning from local experimentation depends on a number of jurisdictions carrying out the same policy experiment. But the incentive to free-ride on the experimentation of others goes up with the number of jurisdictions. If you are one of only a few jurisdictions attempting the policy, there is little to learn, if you are one of many, and it is best to let the others pay the price of experimentation.

Volden (1996) suggests that, when the experimenting states have similar goals and abilities, but the policies they choose to try are different, then we have the most to learn from experimentation. Unfortunately, the implicit controls on goals and abilities among localities (assuming this is possible) do not help us much in making inferences because the hypotheses being tested are not the same.

Any local policy will have wider effects that will be extremely challenging to evaluate. As an example, Burtraw & Shobe (2008) describe some of the difficulties in evaluating the outcomes from state renewable portfolio standards (RPS). All of the RPS policies are different, the circumstances of implementation are different, states are connected to the same grid, and states implement other policies simultaneously. That states often follow similar policy pathways long before these difficulties can be resolved would seem to indicate some other type of learning going on.²¹

As emphasized by Ostrom (2010, 2012) local governments have incentives to make best use of local resources and design local institutions adapted to local circumstances. This polycentric governance view of policy emphasizes the ability of members of a local community to engage in bargaining and find a reasonably sustainable resource management regime that matches the specific character of the community and its resources. But this process is one of adaptation to special circumstances, not of experimentation over generally applicable new models of resource governance. This custom builder model of local policy discovery does not depend on experiment or on interjurisdictional competition.

Once we admit interjurisdictional environmental spillovers or vertical policy competition among jurisdictional levels, the case is weaker still because local policy entrepreneurship will be focused on maximizing local gains from spillovers even if possibly detrimental to others (Breton 2008).

Policy innovation at the local level serves local interests. Thus, it should not surprise us if the federalist laboratories experiment with ways to limit the effect of national policies on local interests. Or localities may want to find the most effective "beggar thy neighbor" innovations,²² maximizing their gain from spillovers into neighboring jurisdictions without running afoul of existing obligations. If a national emission tax hurts local business, it may be profitable to shift the

²¹It is certainly possible that some voters in the jurisdiction know if they have benefitted, even if the larger-scale effects are unknown. This may be the only information needed for casting a vote.

²²Biofuel mandates in support of local corn farmers might be an apt example. An early primary state might be able to sell this innovation to a national political entrepreneur.

local tax burden off of those firms most affected. This will serve to blunt the effectiveness of the national tax. Not all laboratories are dedicated to longer-lasting lightbulbs.

In the search for examples of local policy innovation, the higher frequency of local decision making may appear as policy leadership, when it is really just a matter of getting across the finish line first. The example of the SO₂ cap and trade program under the US acid rain provisions in the 1990 Clean Air Act is particularly relevant in the context of environmental federalism and illustrates the hazard in inferring a causal relation. It has been observed that, before the passage of the 1990 act, some states and localities had experimented with trading programs for controlling emissions (and fish harvesting). This local experimentation may have facilitated the national adoption of cap and trade (Goulder & Stavins 2011), or maybe not.

The treatment of emission trading in the academic literature in the 1970s and 1980s is replete with references to the advantages of quantity-based or rights-based regulatory design. And, in fact, the EPA had for some years been experimenting with increasing compliance flexibility by allowing emission “exchange” under bubbles or using offsets. Individual transferable quota regulation of fisheries was already in place in New Zealand and Australia. With 50 states and one national government, the chance that a state might be the first to actually try a trading program, even on a small scale, seems high without any need for an assumption that states are a particularly effective locus of policy experimentation. Such examples are completely consistent with myopic policy choices (Volden et al. 2008).

Policy announcements in the absence of proven effectiveness might serve a completely different purpose altogether: signaling a willingness to cooperate (Barrett 2010). It is possible that a locality wishes to send a signal of a willingness to cooperate in solving a larger spillover problem. Implementing the fully cooperative policy alone may be impractical due to the potential for economic and emission leakage. A locality wishing to cooperate might signal that willingness by implementing a first shot, a modest contribution to the global public good, and wait to see if others offer to reciprocate. A trust-building exercise need not start with the expected global policy agreement, but rather imposes a modest local cost in the direction of cooperation.²³

Regional emission trading programs, such as the EU Emission Trading System and the US Regional Greenhouse Gas Initiative, could be interpreted in this light. In the absence of national policy, the member states wish to signal a willingness to cooperate with the establishment of a global or national program to regulate GHGs. The local cap is binding, although the potential for leakage requires that the market price be lower than it would be under a global or national cap. The more states that cooperate, the greater the coalition of those willing to support a national policy. Whatever reductions do occur in the meantime support the case for a willingness to cooperate.

Policy signaling, though, is not the same as policy innovation. It is not about discovery but about negotiation and building trust and reciprocity among jurisdictions. Plus, it is worth keeping in mind that jurisdictions opposed to national policy initiatives can also form coalitions aiming to defeat national initiatives.

FIT: FEDERALISM AND LINKED COMPLEX ADAPTIVE SYSTEMS

Increasing pressure on planetary boundaries adds urgency to the case for integrating socio-ecological models with models of environmental federalism. Paradoxically, the renewed emphasis on resilience of complex adaptive systems may offer an additional rationale for the modularization or decentralization of governance institutions.

²³ Libecap (2014) provides a good summary of transaction costs in international efforts to control GHG emissions. Negotiations between second-tier jurisdictions probably have similar properties.

The future of environmental federalism will increasingly be concerned with how our existing political demarcations, with their slowly evolving institutions, interact with the many dimensions of global ecological change. Human socioeconomic systems have reached a magnitude of energy and resource flows that is rapidly increasing the marginal intensity of interaction with Earth's physical and biological processes. The socioeconomic system that characterizes human activities and the physical and biological planetary systems are becoming ever more closely linked complex adaptive ecological systems (Arrow et al. 2014). These linked systems are subject to large uncertainties, tipping points, and highly nonconvex outcomes (Brock & Starrett 2003).

There is a developing literature on adaptive and polycentric governance of complex adaptive systems (Colding & Barthel 2019, Dorsch & Flachsland 2017) that has yet to be integrated with the economic analysis of environmental federalism. Merging the analysis of complex adaptive systems into the economic analysis of federalism is an important emerging focus for the field of environmental federalism.

Barbier (2011a) makes a strong case that increasing population and per capita consumption along with the nonexcludability of many ecosystem services raise the prospect of steeply increasing costs of either replacing or doing without many valuable ecosystem services. A poor fit between ecosystem properties and regime attributes risks increasing the human costs from poorly managed ecosystems (Carpenter et al. 2012, Young 2002).

Environmental systems have characteristics that make establishing a coherent management regime extremely challenging. Most obviously, many are global in scope: atmospheric chemistry, ocean systems, migratory animals, disease organisms, and antibiotic effectiveness. Environmental systems do not, except in rare cases, honor jurisdictional boundaries (Barbier 2011a). The water cycle, for example, is a mix of local, regional and global attributes with cross-cutting interactions: rivers, aquifers, and patterns of rainfall and ice accumulation interact geographically and seasonally, with both fast and slow changes (Walker et al. 2012). Ecosystem services often have high levels of unpredictability, including possible tipping points and other nonlinearities. These are challenging resource management problems even within a single jurisdiction, much less with diverse jurisdictions that interact in the physical, economic, and political dimensions.

There is no truly encompassing jurisdiction for many ecosystem services. This implies that there will be interactions in values cutting across boundaries (that is, spillovers). Wilson (2003) has suggested a potentially useful analytical approach by drawing an analogy between decomposable subsystems in organization theory and ecological patches. A decomposable subsystem of a larger organization is a division where internal interactions dominate external interactions. In this case, jurisdiction definition would be closely related to ecological connections. Matching institutional scale to frequent interactions matches institutional control to the intensity of ecological relationships and reduces the need for costly contracting across divisions.

Modern federalism analysis has recently tended to deemphasize the idea that some policy maker can assign responsibility for a problem to a particular governance level based on some optimal resource management analysis. First, this assignment is inherently a political decision. Second, existing jurisdictions do not match ecosystem patches in any coherent way, but these governance structures are very sticky, and efforts to create special jurisdictions to deal with spillovers have produced very mixed outcomes (Berry 2009).

A different approach is taken in the burgeoning literature connecting human and natural adaptive systems (Carpenter & Brock 2004, Crépin et al. 2011, Mäler et al. 2003, Runyan et al. 2015). This literature explicitly models strategic and adaptive responses of interacting human institutions and ecological systems but without modeling the internal, political decision processes within those institutions. As human activities push more global systems outside historical ranges and across planetary boundaries, the linked socioeconomic and ecological systems are likely

becoming increasingly fragile and subject to rapid and costly change (Walker et al. 2009, 2012). The increasing fragility in the face of ever more extreme shocks to linked complex adaptive systems increases the importance of managing systemic global risks (Centeno et al. 2015).

Concerns over the increasing fragility of linked human and natural systems have given rise to a large and rapidly growing literature on developing adaptive governance institutions for determining human responses to changes in linked ecological systems (Berkes 2017, Hamilton & Lubell 2018, Preiser et al. 2018). As described in Folke et al. (2005, p. 441), the adaptive governance literature concentrates on experiences of adaptive governance of socio-ecological systems during periods of abrupt change (crisis) and investigates social sources of renewal and reorganization. Studies of adaptive governance connect individuals, organizations, agencies, and institutions at multiple organizational levels. Key persons provide leadership, trust, vision, and meaning, and they help improve institutional learning and responsiveness.

The joint emphasis on the details of local institutional development has led to considerable cross-pollination between this adaptive governance literature and the empirical literature on polycentric governance of common pool resources (Ostrom 2010), but there are as yet no links between the study of adaptive governance at multiple levels and the literature on federalism. In fact, a large and growing divide separates the ecological governance literature from the literature on federalism and environmental federalism in particular. The studies of adaptive governance do not yet include any direct consideration of horizontal and vertical competition between jurisdictions, equilibrium interactions among local policies, or the rich models of political decision making (Oates 2008).

Much the same can be said for the literature on polycentric governance. Like the adaptive governance literature, the polycentric governance literature emphasizes self-organization, location-specific circumstances, local experimentation and learning, and the building of trust (Dorsch & Flachsland 2017). The lengthy list of site-specific factors that determine the effectiveness of local governance institutions in managing local common pool resources makes generalizations about how to facilitate good governance quite difficult (Agrawal 2003a, Libecap 1989). And this is before we acknowledge the importance of spillovers among jurisdictions. One important lesson in the study of local common pool resource management institutions is that they become more fragile as the geography expands and as uncertainty over external influences grows (Agrawal 2003a). Spillovers make local cooperation harder (Agrawal 2003b). This is consistent with the transaction-cost approach to institutional evolution (Barbier 2011b).

A challenge for the polycentric governance approach is how to include explicit models of learning and of multilevel political governance among closely linked jurisdictions. We know that local policy experiments are often quite hard to evaluate, even for local effects, as compared to some counterfactual policy possibilities. The process by which localities and local institutions learn is not well understood. We also know that, in the presence of spillovers, a locality may have as much interest in interfering with policies made at other levels as it does in cooperating with those policies.

The environmental federalism literature, on the other hand, has yet to pay due attention to some factors that we know to be important in the success of local governance: local social capital and the institutional framework for generating trust and reciprocity (Falk et al. 2003). While the consequences of the generally poor fit between jurisdictions and ecosystem patchiness are of central concern in the adaptive governance literature, considerably less attention is paid to poor fit in much of the work on environmental federalism. Little effort has been made to link the models of political decision making in nested jurisdictions with models of fast and slow ecological change at different scales (Crépin et al. 2011, Walker et al. 2012). An effort to bridge the analysis of complex adaptive ecosystems with that of fiscal and environmental federalism is an important frontier for environmental federalism research (Carpenter et al. 2012).

Given the conclusion of many ecological researchers that ecological systems may be becoming less robust and resilient due to pressures from human activities, a great emphasis in recent governance studies,²⁴ outside of the fiscal federalism literature, is on ways to increase the resilience of the linked human and natural systems (Carpenter et al. 2012, Duit 2016). Carpenter et al. (2012) list nine “enabling conditions for general resilience” of linked human and natural linked complex adaptive systems:

1. Diversity
2. Modularity
3. Openness
4. Reserves
5. Feedbacks
6. Nestedness
7. Monitoring
8. Leadership
9. Trust

This list seems almost like a backdoor definition of decentralization. Localities exhibit a wide diversity of preferences and endowments. Localities with some independent powers of governance are modular and nested, in the sense that they will respond differently to shocks and have some capacity to break the transmission of negative shocks across jurisdictions. At the subnational level, localities are open to the relatively free movement of labor, capital, and other mobile resources. Although somewhat less certain, lower-level jurisdictions may offer more opportunity for interactions that can allow direct monitoring, feedback, and the development of trust. The list of characteristics that make ecosystems more robust and resilient maps well to some amount of governance decentralization.

We know from earlier parts of our discussion that, once we account for interactions, uncertainties, differences in preferences, and inherently imperfect political mechanisms, decentralization cannot be counted on for many of the benefits for which it seems suited a priori (Treisman 2007). In the context of large-scale spillovers, decentralization has even less to recommend it. An emphasis on resilience may work in the opposite direction.

How jurisdictional political decision making interacts with nonlinearities and uncertainties in ecosystems adds another layer of complication that has yet to be addressed in the federalism literature. Studies of ecosystems with nonlinear responses to shocks have raised questions about a social planner’s ability to optimally manage these resources with a tax mechanism (Crépin et al. 2011, Levin et al. 2013, Mäler et al. 2003). An ownership mechanism may be more robust, if available (Carpenter & Brock 2004). This analysis of the management of complex adaptive systems suggests an asymmetry between price and quantity regulatory mechanisms based on the interaction of socioeconomic adaptive approaches and ecosystem responses.

In my earlier analysis of decentralized policy in the presence of spillovers, I showed that, where lower jurisdictions have different preferences toward the control of a global public good, then these jurisdictions, by making their best response to a national policy, can move the national outcome away from the policy chosen at the national level. In the case of a national tax on emissions, localities can use their own policy portfolio to blunt the incidence of the national tax on local emitters raising national emissions. Of course, other localities might do the opposite and lower emissions below what would occur with the national tax. A national cap eliminates the ability of

²⁴For a recent critical review, see Colding & Barthel (2019).

lower-level jurisdictions to increase emissions, although local policies can change the market price of emissions.

With linked complex systems, giving localities the option of using local policies to increase exploitation of the resource will increase the risk of a potentially very costly transition from a productive to an unproductive equilibrium (Runyan et al. 2015). Using a tax (that is, a price-based regulatory instrument) allows localities this option, while using a quantity instrument does not. With a quantity instrument, a locality may impose a cost on itself to increase exploitation of the resource, but this will not increase overall exploitation, since there must be equal reductions elsewhere. A locality may reduce total exploitation by not using or retiring some of the national allowable resource use. This is of less concern, as it would move the at-risk resource further away from any risky tipping points.

In the presence of potential nonlinear responses in multijurisdiction public goods, a quantity instrument has a greater likelihood than a tax instrument of avoiding costly nonlinearities. This implies that localities can be allowed more autonomy under a quantity instrument than under a tax instrument. In this way, quantity instruments can preserve many of the enabling conditions for general resilience. Jurisdictions can retain a large measure of control over local policy toward the regulated resource without placing the resource at greater risk. Local control could possibly be enhanced by direct allocation of resource use rights (allowances) to some non-national jurisdictional level with localities having the right to use their allowances as they see fit. Doing so would seem to facilitate the diverse and modular connectedness of localities while still implementing the control over resource use consistent with avoiding the risk of overexploitation were localities to have the independent ability to raise the intensity of resource use (Garcia-Mila et al. 2017).

CONCLUSION

The increasing tendency of human activities to breach planetary boundaries on the safe levels of interaction with various ecosystem services has generated rising levels of concern over the robustness and resilience of human institutions (Walker et al. 2009). Human interactions with global and regional ecosystem services are mediated through a nested set of governance institutions that have developed under historical circumstances largely unrelated to current global environmental stresses. Environmental federalism, as a discipline of inquiry, concerns itself broadly with the interactions between these nested governance institutions and ecosystem services.

When an all-powerful and politically unconstrained social planner is faced with spillovers that cannot be corrected through contracting, a standard result in the environmental federalism literature is to move the responsibility up to the lowest jurisdiction that encompasses the spillovers but no higher. This result depends on the persistent default preference for local governance with strong Wicksellian connections between revenues and expenditures. The social planner at the higher level will then set the optimal level of the public nuisance for the nested jurisdictions affected by the spillovers.

There are a number of difficulties with this view. First, with the advent of rigorous models of endogenous political decision making, it is no longer tenable to stop with what the social planner would do, even if one wishes to undertake this exercise to provide a benchmark for the analysis (Oates 2005). Second, once the preference aggregation and agency problems of political decision making are introduced, then outcomes are sensitive to the dispersion and distribution of preferences over the public nuisance in question. Third, because localities will make their best strategic response to higher-level policy decisions, the actual amount of emission control will depend on which policy instrument is used at the higher level. A price instrument allows local jurisdictions to move the actual amount of emissions away from the level determined at the higher jurisdiction

level. The higher jurisdiction has some power to preempt local options, but only within limits. One of those limits is the potential for secession of lower jurisdictions.

Local policy experimentation along these lines suggested in the model of laboratory federalism has long served as a rationale for policy decentralization. On closer examination, these experiments lack key design features that make experiments informative. Our models of policy learning from local policy experimentation are still incomplete, and other explanations for observed patterns of local policy development, such as signaling willingness to cooperate, are possibly better at explaining observed patterns of policy development and diffusion.

As concerns over large-scale public bads and breached planetary boundaries have escalated, distinct lines of investigation into how to manage large-scale public goods have developed. One strand of investigation examines the interaction between linked socioeconomic and ecosystem complex adaptive systems. These linked systems are subject to highly nonlinear interactions and unpredictable transitions between high-value and low-value states.

Unfortunately, the investigations of complex adaptive systems and adaptive governance institutions have developed without any reference to the valuable insights in the environmental federalism literature. This lack of communication across lines of investigation means that the important insights concerning the inherently political nature of jurisdictional decision making have not had noticeable influence on the adaptive governance investigations.

There are references in some studies of the governance of complex adaptive systems to the limitations of price-based regulatory mechanisms for the management of nonlinear systems. Some studies speculate that rights-based or quantity-based regulatory mechanisms may work better for managing linked adaptive systems. One implication of this line of investigation is that the implementation of a quantity-based regulatory mechanism established at a higher jurisdiction, because it maximizes local autonomy subject to avoiding key tipping points, appears more likely to maintain some of the desirable robustness and resilience properties that local diversity and modularity bring to adaptive systems.

My purpose in raising this point is to demonstrate the importance of reintegrating the investigations of environmental federalism with studies of linked complex adaptive socio-ecological systems. It is possible that a closer linking of socio-ecological models with models of environmental federalism may provide an unexpected new justification for decentralized resource governance.

DISCLOSURE STATEMENT

The author is not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENT

I am indebted to an anonymous reviewer for many very helpful suggestions.

LITERATURE CITED

- Agrawal A. 2003a. Common resources and institutional sustainability. In *The Drama of the Commons*, ed. E Ostrom, T Dietz, N Dolšák, PC Stern, S Stonich, EU Weber, pp. 41–85. Washington, DC: Natl. Acad. Press
- Agrawal A. 2003b. Sustainable governance of common-pool resources: context, methods, and politics. *Annu. Rev. Anthropol.* 32:243–62
- Ahmad E, Brosio G, eds. 2008. *Handbook of Fiscal Federalism*. Cheltenham, UK: Edward Elgar

- Arrow KJ, Ehrlich PR, Levin SA. 2014. Some perspectives on linked ecosystems and socioeconomic systems. In *Environment and Development Economics*, ed. S Barrett, K-G Mäler, ES Maskin, pp. 95–116. Oxford, UK: Oxford Univ. Press
- Barbier E. 2011a. *Capitalizing on Nature: Ecosystems as Natural Assets*. Cambridge, UK: Cambridge Univ. Press
- Barbier E. 2011b. Transaction costs and the transition to environmentally sustainable development. *Environ. Innov. Soc. Transit.* 1:58–69
- Barrett S. 2010. *Why Cooperate? The Incentive to Supply Global Public Goods*. Oxford, UK: Oxford Univ. Press
- Berkes F. 2017. Environmental governance for the Anthropocene? Social-ecological systems, resilience and collaborative learning. *Sustainability* 9:1232
- Berry CR. 2009. *Imperfect Union: Representation and Taxation in Multilevel Governments*. Cambridge, UK: Cambridge Univ. Press
- Bird RM, Slack E. 2014. Local taxes and local expenditures in developing countries: strengthening the Wicksellian connection. *Public Adm. Dev.* 34:359–69
- Boffa F, Piolatto A, Ponzetto GAM. 2016. Political centralization and government accountability. *Q. J. Econ.* 131(1):381–422
- Boulding K. 1966. The coming economics of Spaceship Earth. In *Environmental Quality in a Growing Economy*, ed. H Jarrett, pp. 3–14. Baltimore, MD: Resour. Future/Johns Hopkins University Press
- Breton A. 2008. Modeling vertical competition. See Ahmad & Brosio 2008, pp. 86–105
- Brock WA, Starrett D. 2003. Managing systems with non-convex positive feedback. *Environ. Resour. Econ.* 26(4):575–602
- Burtraw D, Shobe W. 2008. Local options on global stocks: how the states are affecting the U.S. debate on climate policy. In *States and Climate Change: Leaders or Lab Rats?*, ed. J Domanski, pp. 43–67. Princeton, NJ: Policy Res. Inst. Region
- Burtraw D, Shobe W. 2009. *State and local climate policy under a national emissions floor*. Discuss. Pap. 09-54, Resour. Future, Washington, DC. <https://media.rff.org/documents/RFF-DP-09-54.pdf>
- Burtraw D, Woerman M. 2013. Economic ideas for a complex climate policy regime. *Energy Econ.* 40:S24–31
- Cai H, Treisman D. 2009. Political decentralization and policy experimentation. *Q. J. Political Sci.* 4(1):35–58
- Carpenter S, Arrow K, Barrett S, Biggs R, Brock W, et al. 2012. General resilience to cope with extreme events. *Sustainability* 4(12):3248–59
- Carpenter SR, Brock WA. 2004. Spatial complexity, resilience, and policy diversity: fishing on lake-rich landscapes. *Ecol. Soc.* 9(1):8
- Centeno MA, Nag M, Patterson TS, Shaver A, Windawi AJ. 2015. The emergence of global systemic risk. *Annu. Rev. Sociol.* 41:65–85
- Cheikbossian G. 2008. Rent-seeking, spillovers and the benefits of decentralization. *J. Urban Econ.* 63(1):217–28
- Colding J, Barthel S. 2019. Exploring the social-ecological systems discourse 20 years later. *Ecol. Soc.* 24(1):2
- Crépin A-S, Norberg J, Mäler K-G. 2011. Coupled economic-ecological systems with slow and fast dynamics—modelling and analysis method. *Ecol. Econ.* 70(8):1448–58
- Dalmazzone S. 2008. Decentralization and the environment. See Ahmad & Brosio 2008, pp. 459–77
- Desmet K, Rossi-Hansberg E. 2015. On the spatial economic impact of global warming. *J. Urban Econ.* 88:16–37
- Diamond J. 1997. *Guns, Germs and Steel: The Fates of Human Societies*. New York: W.W. Norton
- Dijkstra BR, Fredriksson PG. 2010. Regulatory environmental federalism. *Annu. Rev. Resour. Econ.* 2:319–39
- Dorsch MJ, Flachsland C. 2017. A polycentric approach to global climate governance. *Glob. Environ. Politics* 17(2):45–64
- Duit A. 2016. Resilience thinking: lessons for public administration. *Public Adm.* 94(2):364–80
- Eaton S, Kostka G. 2018. What makes for good and bad neighbors? An emerging research agenda in the study of Chinese environmental politics. *Environ. Politics* 27(5):782–803
- Eichenberger R, Frey B. 2008. Functional, overlapping and competing jurisdictions (FOCJ): a complement and alternative to today's federalism. See Ahmad & Brosio 2008, pp. 154–81

- Falk A, Fehr E, Urs F. 2003. Appropriating the commons: a theoretical explanation. In *The Drama of the Commons*, ed. E Ostrom, T Dietz, N Dolšák, PC Stern, S Stonich, EU Weber, pp. 154–91. Washington, DC: Natl. Acad. Press
- Fell H, Kaffine DT. 2014. Can decentralized planning really achieve first-best in the presence of environmental spillovers? *J. Environ. Econ. Manag.* 68(1):46–53
- Fischel W. 2001. Municipal corporations, homeowners and the benefit view of the property tax. In *Property Taxation and Local Government Finance: Essays in Honor of C. Lowell Harris*, ed. WE Oates, pp. 33–77. Cambridge, MA: Lincoln Inst. Land Policy
- Folke C, Hahn T, Olsson P, Norberg J. 2005. Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.* 30:441–73
- Garcia-Mila T, McGuire TJ, Oates W. 2017. *Strength in diversity? Fiscal federalism among the fifty U.S. states*. Work. Pap. 1001, Barcelona Grad. Sch. Econ.
- Goulder LH, Stavins RN. 2011. Challenges from state-federal interactions in US climate change policy. *Am. Econ. Rev.* 101(3):253–57
- Hamilton M, Lubell M. 2018. Collaborative governance of climate change adaptation across spatial and institutional scales. *Policy Stud. J.* 46(2):222–47
- Hinkelmann K, Kempthorne O. 1994. *Design and Analysis of Experiments*. Hoboken, NJ: Wiley
- Inman RP. 1985. Markets, governments and the new political economy. In *Handbook of Public Economics*, Vol. 2, ed. AJ Auerbach, M Feldstein, pp. 647–777. Amsterdam: North-Holland
- Koethenbuenger M. 2008. Revisiting the “Decentralization Theorem”—on the role of externalities. *J. Urban Econ.* 64(1):116–22
- Levin S, Xepapadeas T, Crépin A-S, Norberg J, de Zeeuw A, et al. 2013. Social-ecological systems as complex adaptive systems: modeling and policy implications. *Environ. Dev. Econ.* 18(2):111–32
- Libecap GD. 1989. *Contracting for Property Rights*. Cambridge, UK: Cambridge Univ. Press
- Libecap GD. 2014. Addressing global environmental externalities: transaction costs considerations. *J. Econ. Lit.* 52(2):424–79
- Lipscomb M, Mobarak AM. 2016. Decentralization and pollution spillovers: evidence from the re-drawing of county borders in Brazil. *Rev. Econ. Stud.* 84(1):464–502
- Lockwood B. 2008. The political economy of decentralization. See Ahmad & Brosio 2008, pp. 33–60
- Lorz O, Willmann G. 2005. On the endogenous allocation of decision powers in federal structures. *J. Urban Econ.* 57(2):242–57
- Mäler K-G, Xepapadeas A, de Zeeuw A. 2003. The economics of shallow lakes. *Environ. Resour. Econ.* 26(4):603–24
- McCann L. 2013. Transaction costs and environmental policy design. *Ecol. Econ.* 88:253–62
- Millimet D. 2014. Environmental federalism: a survey of the empirical literature. *Case West. Reserve Law Rev.* 64(4):1669–1757
- Nechyba T. 2001. The benefit view and the new view: Where do we stand, twenty-five years into the debate? In *Property Taxation and Local Government Finance*, ed. W Oates, pp. 114–21. Cambridge, MA: Lincoln Inst. Land Policy
- North DC. 1990. *Institutions, Institutional Change, and Economic Performance*. Cambridge, UK: Cambridge Univ. Press
- Oates W. 2004. A reconsideration of environmental federalism. In *Recent Advances in Environmental Economics*, ed. J List, A de Zeeuw, pp. 1–32. Cheltenham, UK: Edward Elgar
- Oates W. 2005. Toward a second-generation theory of fiscal federalism. *Int. Tax Public Finance* 12(4):349–73
- Oates W. 2008. On the evolution of fiscal federalism: theory and institutions. *Natl. Tax J.* 61(2):313–34
- Ostrom E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge, UK: Cambridge Univ. Press
- Ostrom E. 2010. Polycentric systems for coping with collective action and global environmental change. *Glob. Environ. Change* 20(4):550–57
- Ostrom E. 2012. Nested externalities and polycentric institutions: Must we wait for global solutions to climate change before taking actions at other scales? *Econ. Theory* 49(2):353–69

- Preiser R, Biggs R, De Vos A, Folke C. 2018. Social-ecological systems as complex adaptive systems: organizing principles for advancing research methods and approaches. *Ecol. Soc.* 23(4):46
- Rose-Ackerman S. 1980. Risk taking and reelection: Does federalism promote innovation? *J. Leg. Stud.* 9(3):593–616
- Rubinfeld DL. 1985. The economics of the public sector. In *Handbook of Public Economics*, Vol. 2, ed. AJ Auerbach, M Feldstein, pp. 571–645. Amsterdam: North-Holland
- Runyan CW, D’Odorico P, Shobe W. 2015. The economic impacts of positive feedbacks resulting from deforestation. *Ecol. Econ.* 120:93–99
- Shobe W, Burtraw D. 2012. Rethinking environmental federalism in a warming world. *Clim. Change Econ.* 3(4):1250018. <https://doi.org/10.1142/S2010007812500182>
- Sigman H. 2002. International spillovers and water quality in rivers: Do countries free ride? *Am. Econ. Rev.* 92(4):1152–59
- Sigman H. 2005. Transboundary spillovers and decentralization of environmental policies. *J. Environ. Econ. Manag.* 50(1):82–101
- Sorens JP. 2016. Secession risk and fiscal federalism. *Publius J. Fed.* 46(1):25–50
- Strumpf KS. 2002. Does government decentralization increase policy innovation? *J. Public Econ. Theory* 4(2):207–41
- Treisman D. 2004. Rational appeasement. *Int. Organ.* 58(2):345–73
- Treisman D. 2007. *The Architecture of Government: Rethinking Political Decentralization*. Cambridge, MA: Cambridge Univ. Press
- Ventura J. 2019. Sharing a government. *J. Eur. Econ. Assoc.* 17(6):1723–52
- Volden C. 1996. Entrusting the states with welfare reform. In *The New Federalism: Can the States Be Trusted?*, ed. J Ferejohn, B Weingast, pp. 65–96. Stanford, CA: Hoover Inst. Press
- Volden C, Ting MM, Carpenter DP. 2008. A formal model of learning and policy diffusion. *Am. Political Sci. Rev.* 102(3):319–32
- Walker B, Barrett S, Polasky S, Galaz V, Folke C, et al. 2009. Looming global-scale failures and missing institutions. *Science* 325(5946):1345–46
- Walker B, Carpenter S, Rockstrom J, Crépin A-S, Peterson G. 2012. Drivers, “slow” variables, “fast” variables, shocks, and resilience. *Ecol. Soc.* 17(3):30
- Weiland PS. 2000. Federal and state preemption of environmental law: a critical analysis. *Harv. Environ. Law Rev.* 24:237
- Williams RC. 2012. Growing state-federal conflicts in environmental policy: the role of market-based regulation. *J. Public Econ.* 96(11):1092–99
- Wilson J. 2003. Scientific uncertainty, complex systems, and the design of common-pool institutions. In *The Drama of the Commons*, ed. E Ostrom, T Dietz, N Dolšák, PC Stern, S Stonich, EU Weber, pp. 327–59. Washington, DC: Natl. Acad. Press
- Young OR. 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. Cambridge, MA: MIT Press
- Zodrow G. 2001. Reflections on the new view and the benefit view of the property tax. In *Property Taxation and Local Government Finance*, ed. W Oates, pp. 79–110. Cambridge, MA: Lincoln Inst. Land Policy

Contents

Autobiographical

- A Conversation with Angus Deaton
Angus Deaton, Gordon Rausser, and David Zilberman 1

Resource Economics

- Climate Change and Forests
Brent Sohngen23
- The Effectiveness of Forest Conservation Policies and Programs
Jan Börner, Dario Schulz, Sven Wunder, and Alexander Pfaff45
- Harnessing Advances in Agricultural Technologies to Optimize Resource
Utilization in the Food-Energy-Water Nexus
Ruiqing Miao and Madhu Khanna65

Agricultural Economics

- Pricing Strategies of Food Retailers
Stephen F. Hamilton, Jura Liaukonyte, and Timothy J. Richards87
- Relational Contracts in Agriculture: Theory and Evidence
Jeffrey D. Michler and Steven Y. Wu 111
- Concentration in Seed and Biotech Markets: Extent, Causes, and Impacts
Koen Deconinck 129
- The Microeconomics of Agricultural Price Risk
Chris M. Boyd and Marc F. Bellemare 149
- Sustainability-Related Food Labels
Daniele Asioli, Jessica Aschemann-Witzel, and Rodolfo M. Nayga Jr. 171

Environmental Economics

- Eco-Labels: Modeling the Consumer Side
Klaas van 't Veld 187

Payments for Environmental Services: Past Performance and Pending Potentials <i>Sven Wunder, Jan Börner, Driss Ezzine-de-Blas, Sarah Feder, and Stefano Pagiola</i>	209
Mainstream and Heterodox Approaches to Water Quality Valuation: A Case for Pluralistic Water Policy Analysis <i>Bonnie L. Keeler</i>	235
Emerging Issues in Decentralized Resource Governance: Environmental Federalism, Spillovers, and Linked Socio-Ecological Systems <i>William Shobe</i>	259
Stranded Assets in the Transition to a Carbon-Free Economy <i>Frederick van der Ploeg and Armon Rezai</i>	281
Climate Change and the Financial System <i>Irene Monasterolo</i>	299
Development Economics	
Environmental, Economic, and Social Consequences of the Oil Palm Boom <i>Matin Qaim, Kibrom T. Sibhatu, Hermanto Siregar, and Ingo Grass</i>	321
The Impact of Nutritional Interventions on Child Health and Cognitive Development <i>Christian Bommer, Nitya Mittal, and Sebastian Vollmer</i>	345
Is Emigration Harmful to Those Left Behind? <i>Frédéric Docquier and Stefanija Veljanoska</i>	367
Transportation and the Environment in Developing Countries <i>Shanjun Li, Jianwei Xing, Lin Yang, and Fan Zhang</i>	389
Recent Advances in the Analyses of Demand for Agricultural Insurance in Developing and Emerging Countries <i>Williams Ali, Awudu Abdulai, and Asbok K. Mishra</i>	411
Methodological Approaches	
What Can We Learn from Experimenting with Survey Methods? <i>Joachim De Weerd, John Gibson, and Kathleen Beegle</i>	431
Uncertainty in Population Forecasts for the Twenty-First Century <i>Nico Keilman</i>	449

The Evolution of Integrated Assessment: Developing the Next
Generation of Use-Inspired Integrated Assessment Tools
Karen Fisher-Vanden and John Weyant 471

Errata

An online log of corrections to *Annual Review of Resource Economics* articles may be found at <http://www.annualreviews.org/errata/resource>