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Abstract

Climate change requires action at multiple levels of government. We focus on the potential for climate change policy creation among small rural governments in the US. We argue that co-production of scientific knowledge and policy is a communicative approach that encompasses local knowledge flowing up from rural governments as well as expertise and power (to coordinate and ensure compliance) flowing down from higher level authority. Using environmental examples related to land use policy, natural gas hydro-fracturing, and watershed protection, we demonstrate the importance of knowledge flows, power, and coordination in policy creation. Co-production of knowledge and policy requires respect for local knowledge and a broader framing of issues to include both environmental and economic perspectives. While we see potential for local action, we caution that polycentric approaches lead to externality problems that require multilevel governance to ensure coordination and compliance.

Introduction

Climate change is one of the most contentious areas of public policy in the United States. Even though international talks on climate change have stalled, the potential exists to move forward with local governments, which are well positioned to address some of the problem of greenhouse gas emissions (Betsill and Bulkeley 2006, Kousky and Schneider 2003, Ostrom 2009). Municipalities in the United States have the power to mitigate emissions through land-use rules, transportation programs, building codes, and other policies. However, the number of local governments engaged in concrete action remains relatively low, particularly among smaller places (Svara 2011). Many American municipalities are small and rural, and lack the technical knowledge and fiscal capacity to act. Many also lack the political will and refuse to accept the conclusions of climate scientists (Carter and Culp 2010).

A special challenge with climate change policy is that much remains unknown. Although scientific understanding is rapidly evolving, agreement about the seriousness of the climate crisis is being undercut by a disinformation campaign (Jacques, Dunlap, and Freeman 2008). Sociology of knowledge recognizes the crucial role of situational context and the interconnections between normative assumptions policy judgments and empirical data. Sociology of science scholars stress the importance of an approach that studies science creation as well as its acceptance and its impact on real world policy (Alrøe and Noe 2010).

A second challenge with climate change is the need to both respect local diversity and develop structures to coordinate local action and knowledge exchange. Land use planners emphasize local perspectives in the formation of environmental, economic, and social equity policies of regional import and within various power structures (Forester 2012). We believe, along with Martins and Richards (1995), that the participation of local stakeholders is critical as their local knowledge sharpens policies and leads to greater acceptance of conclusions. But how much does situational context matter when long-term issues are scaled up to the global level as with climate change (Hanekamp 2009)? Just as knowledge and policy imposed from the top-down may lead to inappropriate action, purely local decision making on regional and global issues, such as climate change, may be ineffective as it faces challenges, such as lack of coordination, externalities, and spillover effects. Linking the knowledge of local stakeholders, including the general public, to higher level technical expertise allows for joint knowledge creation and effective policy action. This co-production approach creates tensions, but also opens the possibility for polycentric action on global issues –

action that is owned and respected at the local level (Ostrom 2009, Healey 2008).

In this article we explore the co-production of knowledge and policy as it relates to climate change and the rural community response. Using examples of environmental policies that relate to climate change, we demonstrate that co-production, which involves two directions of knowledge flows and learning (top-down and bottom-up), is critical. We also emphasize the importance of framing the issue in a wide enough context to promote local stakeholder support among the diversity of rural communities. Given the importance of externalities in environmental policy, we explore the need for a multilevel governance framework to coordinate action and ensure compliance.

In section 2 we demonstrate the importance and potential for a local role in climate change policy. In section 3 we explore three features that make co-production of knowledge and policy so important in climate change: the complex nature of the problem, the need for bi-directional learning (top-down and bottom up), and the need for coordination across a range of actors. Despite the complexity of climate change, local input is required to shape a robust policy response. But externalities and spillovers necessitate that local governments have the power to enforce, particularly in rural areas where centralized sanctioning power may be less effective. In the fourth section, we present several examples that illustrate alternative architectures for environmental management. Through these we examine the challenges and opportunities facing various environmental governance structures among rural communities and demonstrate the value of multilevel governance which balances polycentric local action with the power to coordinate in a multilevel government framework. We conclude with implications co-production of knowledge and policy may have for rural areas in particular.

2. Climate change policy in US municipalities

The history of international governmental climate change policy pays little attention to local action, often requiring only token stakeholder consultation when implementing mitigation strategies (Fogel 2004). However, many municipalities have moved to address climate change issues. In the United States, states and municipalities have been in the forefront of developing policies to reduce greenhouse gas emissions (Hecht 2009). American municipalities have the power to manage their own governmental processes, and they can affect the operations of citizens and the private sector in areas such as land use, transportation, and building

efficiency through education, incentives, or regulation (Betsill and Bulkeley, 2006). Studies across numerous countries indicate that 30 to 50 percent of greenhouse gas emissions can be controlled through local government policies (Lindseth 2004).

The impact of big cities versus rural areas on greenhouse gas production is still being researched. Large urban areas tend to be more carbon efficient than sprawling suburbs or rural communities (Glaeser and Kahn 2010). Many blame cities for 75 percent or more of carbon emissions, though others find that emissions are significantly less, perhaps only 57 percent, with agriculture and forestry accounting for 31 percent (Satterthwaite 2008). Suburban residents emit twice the greenhouse gas emissions as urban dwellers (Hoornweg, Sugar, and Trejos Gómez 2011) and rural commuting comprises a large and growing portion of total miles driven in the United States (Renkow and Hoover, 2000).

Despite such a large portion of emissions emanating from outside of urban cores, the spotlight of local action in the United States falls on big cities. While important, this focus is incomplete. Just one-fourth of the United States population lives in municipalities with more than 100,000 people, and more than half, according to the 2010 Census, reside in smaller jurisdictions of fewer than 25,000 people. Although most live in metropolitan areas within the economic and environmental sphere of a city, each municipality, no matter how small, often acts alone on policies regarding environmental protection, land use, and economic development. In urban and metropolitan areas, population density and agglomeration of business and talent promote knowledge sharing and innovation among municipalities and this permits emergence of regional collaboratives that help member communities exploit economies of scale and funding support for climate change mitigation and adaption (Svara, Read, and Moulder 2011).

However rural and smaller communities lag behind in many ways. Rural areas do not have the resources to undertake natural hazard planning measures on their own (Janssen 2006). Planners in these smaller communities face lack of political will, disbelief in the value of local action, lack of peer communities for learning, lack of resources, and a poor scientific understanding of climate change (Carter and Culp 2010). These challenges lead to lower rates of sustainability policy adoption among smaller and rural places (Homsy and Warner 2012). For example, a national survey of 2,176 US municipalities and counties in 2010 ranging in population size from 2,500 to more than 8,000,000 found that the rate of undertaking greenhouse gas inventories in communities with fewer than 50,000 residents is one-third that of communities with a

population larger than 100,000 – and only one-sixth in communities with fewer than 10,000 residents (Svara, 2011). Just 55 percent of communities smaller than 25,000 in population have conducted energy audits of their buildings, while 93 percent of municipalities with more than 100,000 people have undertaken such basic energy conservation and climate change measures (Homsy and Warner 2012). Interestingly, rural areas tend to slightly outperform suburban areas in terms of general sustainability policy adoption, which is likely due to the ability of suburban areas to free ride on the actions of central cities (Homsy and Warner 2013).

Municipalities do not act alone; legal frameworks at various governmental levels play an important role in shaping the options available to municipalities for open space conservation (Schmidt and Paulsen 2009) and the mitigation of climate change (Schroeder and Bulkeley 2009). Small communities in Sweden that make the most progress in greenhouse gas reduction receive significant assistance from the national government (Langlais 2009).

We argue that local action is crucial in climate change mitigation where the diversity of context and capacity constraints undercut top-down, one-size-fits-all regulation. Rural areas, in particular, seek to reconcile the diverse demands of resource extraction, commodity production, property rights, and environmental protection without the necessary knowledge, structural, fiscal, or political resources (Wolf 2011). By framing the issue from the local perspective, climate change becomes grounded in local realities, such as floods, droughts, or pest infestations. This may lead to more successful policy interventions as rural residents craft policies that respond to their perceptions of and priorities for action (Ostrom 2009, Rayner 2010). However, although a localized approach may help achieve goals of CO2 reduction and climate change adaptation, it will also result in uneven policies. Such a polycentric local approach requires a multilevel governance framework to provide the authority for local action, the scale to promote coordination, and the power to ensure compliance. This is why we give attention to the architecture of a multilevel governance framework in the co-production of knowledge and policy.

3. Co-production of knowledge and policy

The theoretical basis for the co-production of knowledge in addressing climate change occurs in three arenas. First, as a complex, multidisciplinary and global phenomena, climate change science requires a

complex, multi-faceted view. Second, policy and knowledge networks must be open to multiple frames of reference and directions of learning; a simple top-down approach does not work. Finally, attention must be given to power differences and the need to coordinate action across communities. If not, individual actions will lack impact.

Complexity and the Need for Co-Production

The ordering of science through knowledge and technology, and the ordering of society through power and culture create complex interactions (Jasanoff 2004a). A combined order does not come easily as similar events are interpreted through different frames across communities, within nations, and around the globe. Co-production does not give primacy to either the knowledge of science or the knowledge of society but recognizes the importance of both (Jasanoff 2004b).

In the policy making sphere there exist additional divisions beyond the science-society dichotomy. Scientific knowledge generation is typically top-down and urban centric, and, therefore, associated policies tend to emanate from the center and to recommend solutions that assume 'one size fits all', yet climate policies in an urban core may make little sense (physically, culturally, or economically) in most rural communities. Traditional top-down systems promulgate prescriptive regulations, which leave little discretion. They also tend to focus on individual industrial processes and categories of pollution rather than holistic or ecosystem issues. Compliance is viewed as legal enforcement rather than environmental cleanup (Fiorino 2010) with success narrowly defined as uncovering evidence of violations rather than innovative approaches to problem solution (Gore 1997).

Climate change represents an example of what Rittel and Webber (1973) call a 'wicked' problem, which is hard to define, woven intricately into other issues, and defies efforts to contain within boundaries. Climate change intervention strategies must be comprehensive so that a particular action does not just reduce greenhouse gases in one location or time period or for one product, but affects the entire supply chain or life cycle of the activity (McDonough and Braungart 2002, Pauli 2010). The dual scientific/society nature of wicked problems and the fluidity of the processes breed uncertainty and require a multi-faceted approach.

Traditionally, the complexity in rural areas has been ignored; the primary focus of rural policy in the United States is on agricultural production (Bryden and Warner 2012). The lack of a multi-functional view in US agricultural policy leads to a productivist focus that emphasizes simple short-term economic competitiveness over more complicated concerns with equity or long term environmental sustainability (Shortall and Warner 2010). Rural development policy in the European Union has a multi-functional focus uniting agriculture, rural development, and environmental protection (Bryden 2005, Marsden 1999, Shortall 2004). As a result, in the E.U., rural people in particular have come to see themselves as stewards of the rural environment. This sentiment in less pronounced in the US, in part because national policy does not articulate stewardship as a priority.

Local framing/ local knowledge – policies that survive

When people see the natural resource under discussion as important to their own well-being, it increases the likelihood of local action (Ostrom 2009). However, that link is strained when reducing greenhouse gas emissions, which requires short-term costs to the local actor, while the benefits of lowering the gas content in the atmosphere are diffuse, distant in time, and often distant in place. An additional complication is that the impacts of climate change vary considerably from place to place. Increased droughts and floods will negatively impact some rural populations while benefiting others (Jensen 2009). For example, in some rural communities logging companies have profited from harvesting trees killed by increased pine-borer beetle infestations, while other rural communities have lost economic livelihood as the same infestations raise threats of fire and cause declines in recreation.

The federal government in the United States has experimented with forms of multilevel governance, dubbed "cooperative federalism" by legal scholars, in an effort to harness local knowledge and account for place-specific situations. Most common in environmental law, cooperative federalism describes a situation in which state and local governments participate in the implementation of federal standards (Fischman 2005). For example, in the case of permitting cell phone towers, municipalities are allowed to make local land use decisions regarding the site, but within a broader federal framework that facilitates decision-making processes and promotes tower construction (Salkin and Ostrow 2008). However, with primary control at the local level, municipalities simply act as an agent to shape decisions within their own

borders and little information flows up to higher levels or horizontally to other municipalities. A more interactive approach has the federal government setting minimum standards that local governments can exceed; this results in more dialogue among actors and innovation (Sovacool 2008). For example, in California, both the state and federal authorities make decisions to protect endangered species in the Sacramento River Delta (Fischman 2005).

Framing in such cases is critical. Local culture, development history, geographic conditions, and historical events impact local policy proposals (Brennan et al. 2009). Environmental policies regarding climate change must be comprehensive and coupled with economic and social equity to ensure sustainability (Svara et al. 2011). This is particularly true among rural local governments in the United States. Research has shown that links to economic development make rural communities more willing to enact environmental protections (Warner et al. 1999). Co-benefits play an important role because they connect local benefits to the local costs of action, and are often the reason some municipalities decide to tackle climate change in the absence of other drivers (Hamilton and Akbar 2010). Cost savings are a major motivator of municipal greenhouse gas reduction programs (Kousky and Schneider 2003). Another common co-benefit is local public health (Bloomberg and Aggarwala 2008). Such reframing of climate change can transform an abstract concept to a local, tangible, and actionable one (Metz and Below, 2009). However, such an approach might limit success because it suggests that climate change mitigation and economic growth will always be compatible (Toly 2008). Also, localizing climate change in this way might push problems from one community to another, if comprehensive environmental laws and monitoring are not enforced across the rural to urban landscape (Bai 2007).

Rural communities can offer specialized knowledge that makes the co-production of climate change knowledge more effective. Rural areas in the US are diverse; the 'one-size-fits-all' policies handed down from Washington, just do not translate well (Brown et al. 2003). Expert-driven systems, which focus on technical problem solving and treat the world like a machine to be monitored and repaired in parts undermine the potential for democratic engagement in policy decision making (Fiorino 2006, Innes and Booher 2001)). Although higher levels of authority have the power, the top-down imposition of regulations can alienate people, who must act on policy. Top-down approaches leave little room for local innovations and issue framing that links global concerns with local priorities. Local culture and social networks,

particularly among local leaders, are critical in helping rural communities prepare for and respond to crisis (Flora et al. 2003). Rural communities that engage in the production of local knowledge, learn from difference, and allow symbolic diversity and debate are ultimately more willing to invest local resources toward solving problems (Flora and Flora, 1993). A rural community's connection to the natural environment as well as the environmental values of local officials are important motivators for local action on climate change (Homsy 2013).

Ostrom (2009) sees potential in such a polycentric localized approach. The core idea of polycentricity is that the users closest to the resource provide the greatest safeguards; they have the knowledge, desire, and relationships. In addition, the distributed nature of local action provides redundancy, encourages innovation, and increases the overall robustness of the system. Some argue that polycentric systems are harder for free riders to exploit due to difficulty navigating the mix of institutions and actors involved (Dietz et al. 2003). But lack of coordination and sanctioning authority may increase externalities in such distributed approaches to political, economic and social order (McGinnis 1999).

Power and Coordination – The Need for Multilevel Governance

In a co-production system, power is needed to enforce and provide coordination, particularly as the number of players starts to grow. Ostrom (1990) gave voice to the idea that users of common pool resources can self organize and protect local resources – to avoid a tragedy of the commons. Her work shows the value of local knowledge, local control, and local organization in managing environmental problems. However, she describes its success as limited to small groups (Ostrom 2010). For larger scale and longer term environmental issues, such as climate change, the need for coordination across communities in a fragmented governance framework is critical – not only from a knowledge exchange perspective, but also in terms of how the problem is framed, who has power to act, and what happens to externalities. Purely local provision of environmental services does not recognize the critical importance of power and the need for some level of central coordination. Centralized guidance and incentives have been found to be important in local implementation of climate adaptation policies (Brouwer, Rayner, and Huitema 2013).

Kousky and Schneider (2003) found that fiscal co-benefits drive local efforts to reduce greenhouse gases. However, rural local governments often do not have the power to make decisions that would result in

local co-benefits in some areas, such as transportation, the way that large cities do. Lukes (2005) defines three types of power: power over (typical of hierarchical forms), power to (authority to act) and power with (ability to work together in concert). Too often environmental policy has been built from a power over perspective. Climate change policy needs to build shared power that enables actors at all levels to act in concert. Our concern is that such collaboration still needs the power to coordinate and sanction – a power typically reserved to a higher level of government. This concern motivates our attention to multilevel governance in climate change knowledge and policy action.

With a global environmental issue, such as climate change, there is also the potential for standardization, which can result in a more efficient regulatory scheme and provide the uniformity needed to conduct business across a large area (Sovacool and Brown 2009). At the national or global level, there are economies of scale involving data collection and response. Higher levels of governance can reduce the potential of externality and spillover effects between local jurisdictions. Decision making on a community-by-community basis also risks becoming clogged with too many participants, resulting in confusing network relationships, lack of transparency, and ill-defined or parochial missions (Curry 2009).

Reliance on local action also creates coordination problems. Every policy action results in ancillary impacts (Jochem and Madlener 2003). A characteristic of polycentric governance systems is the incentive for one group to internalize benefits and shed negative externalities onto the larger system (Warner 2011a). An institutional framework is needed to mediate these differences by having various parties come together and work out mutually beneficial arrangements (McGinnis and Ostrom 1992). In rural cases, networked governance has co-evolved as both a response to and a driver of environmental change and resource management challenges (Wolf 2011).

Rural communities have experience with horizontal collaboration, especially in government service delivery (Warner 2006). They often face thin private markets for service delivery and need to create a public market of cooperation to address their problems (Warner 2011b). Experience with collaborative approaches is primarily horizontal and functional; the challenge is to build vertical collaboration in a multilevel governance framework that respects the unique knowledge of rural communities. This is the promise of co production of knowledge and policy, which recognizes the potential for neo-endogenous rural development based on a multi-faceted, multilevel governance framework (Shucksmith 2010).

Any promise, however, will not be realized without addressing differences in capacity between rural and urban communities. Rural areas with weak economic development, small tax bases, and limited capacity can be trapped in a vicious cycle of underinvestment (Warner and Pratt 2005). Homsy and Warner (2013) found that smaller municipalities rely more heavily than larger ones on the citizenry to shape and oversee sustainability policies. The study also found professional municipal management is more important to sustainability policy adoption in smaller places than in larger ones, but cities have more technical staff for policy adoption and implementation. Other studies find similar results, for example, Carter and Culp (2010) found rural municipalities in the western United States lack the technical knowledge and fiscal capacity to adopt local climate change policies.

4. Knowledge generation in environmental policy creation

In this section, we use a series of case examples to make clear the drawbacks when local governments produce environmental policy on their own or when policy production is purely centralized without local knowledge. We rely on media and project reports for these examples. While not full case studies, these examples demonstrate the importance of co-production of knowledge and policy and the need for a multilevel governance architecture in which local governments act as more than agents of higher level policy, but partners in its production. We focus our analysis on local governments, which exercise control over numerous sources of greenhouse gas emissions and adaptation policies through their jurisdiction over land use regulations and related transportation policy (Betsill 2001).

For rural areas, settlement patterns and water quality are two arenas where climate change has critical impacts. First, from the perspective of climate change mitigation, we look critically at the links between local land use planning and inefficient settlement patterns. In this first example, we discuss the benefits and limits of the traditional polycentric approaches to land use control at the local level, and the challenge for coordination either through state policy or voluntary networks such as ICLEI – Local Governments for Sustainability. Our second example looks at natural gas extraction, which is typically out of the control of local government,. In this instance, we see the need for communication and knowledge flows up and down levels of government in order to promote co-production of knowledge and policy. Our final example presents a successful co-production process and multilevel governance framework that resulted in

the protection of a large watershed that crosses many rural and urban communities and involves state and federal authorities. A comparison across these examples shows the critical importance of the multilevel governance architecture in polycentric co-production systems, especially for rural areas.

America's fractured land planning system – the limits of polycentrism

Land use regulations – the ability to control physical development – are critical tools in local climate change mitigation and represent one of the few strong powers that local governments have in the United States. The 50 American states establish broad frameworks within which municipalities can act, but land use planning is typically reserved to local discretion (Frug and Barron 2008). Local governments can make decisions on the location, size, density, and aesthetics of buildings and this impacts the settlement patterns and transportation requirements of the community. In many cases, this local control builds on local knowledge and results in physical development that respects local needs and culture. However, the lack of coordinated land use planning across municipalities in a region can also result in sprawl and associated greenhouse gas emissions. Land use decisions are usually made independently of circumstances in neighboring municipalities, including regional environmental concerns, and there is no recourse when the actions of one community negatively impact another. This bottom-up process is markedly different from Europe where, for example, in Germany and England land use regulation is shared among all levels of government with national agencies setting policies for local governments to implement (Schmidt and Buehler 2007, Williams 1999).

Not only is land use policy uncoordinated in the United States, municipalities often compete for real estate development and property taxes engendering hostility between them (Pendall 2003). This can be particularly true in rural and peri-urban communities that have limited economic development opportunities. In fact the communities most likely to chase economic development with business incentives are those with lower tax bases, higher unemployment and who face the highest levels of inter-jurisdictional competition (Warner and Zheng 2013). In such an environment, municipalities have an incentive to promote development that ignores negative environmental spillovers on neighboring communities and the region (Howell-Moroney 2008).

Rural and suburban land use regulations typically encourage low-density development, and the strict separation of land uses makes automobiles a necessity (Ewing 2008). Worldwide transportation

accounts for 13 percent of greenhouse gas emissions (Dulal et al. 2011), but in the US it is twice that level (27 percent) (US EPA 2011). Much of this is attributed to lack of density in settlement patterns and high levels of commuting (Brandes et al. 2010, Andrews 2008, Ewing et al. 2007), especially in rural areas (Renkow and Hoover 2000, Champion and Brown 2012).

Rural and smaller communities have been found to prepare lower quality land use plans, especially in areas of sustainability (Tang 2009). A few states, such as Oregon and California, encourage local governments to coordinate land use to achieve broader environmental goals (Daniels 2001, Barbour and Deakin 2012). Oregon coordinates local land use among rural and urban governments by requiring communities to work together to draw urban growth boundaries that protect forest and farmland, concentrate development, and curb the local spillover impacts of sprawl (Daniels 2001). Also, local planning rules must be consistent with higher level state policies (Abbott et al. 1994). In this way state authority imposes a co-production arrangement that empowers municipal governments, using local knowledge set in specific contexts to shape rules, but within regional goals set by the state. California recently passed legislation, which requires local governments to coordinate land use and transportation planning with the specific goal of decreasing greenhouse gas emissions (Barbour and Deakin 2012). Unfortunately, most states do not offer such a strong coordinating policy framework for local governments.

The lack of guidance from state or federal governments in the United States is problematic given the broad externalities of land use decisions on climate change. The role of incentivizing and coordinating local action has fallen to various non-governmental organizations; the most prominent and illustrative of the challenge of voluntary action is ICLEI Local Governments for Sustainability. This international organization is among the largest seeking to coordinate land use planning in an effort to reduce greenhouse gas emissions. Formed in 1990, with 200 member municipalities, ICLEI has grown to a network of 1,220 local government members in 70 countries with more than 550 in the United States (ICLEI 2008). This transnational network of local governments facilitates the exchange of ideas and information and sets policy goals (Bulkeley and Betsill 2003). ICLEI carries no formal authority, but it does have an impact on members by virtue of the opportunities and resources it offers including technical expertise. ICLEI resources include best management practices, access to protocols to simplify the complicated task of inventorying emissions, target setting, and other forms of “soft regulation” (Bulkeley 2010, p. 237).

With only several hundred member municipalities across the entire United States, ICLEI's lack of penetration into rural communities is not a surprise. Traditionally, such non-profit actors have played a minor role in the efforts of rural areas to govern their natural environments (Wolf 2011). Local and technical capacities are the limiting factors as smaller communities often lack the human resources needed to craft and implement sustainability policies. Approaches based on co-production and polycentrism thus fall short in achieving a broad impact unless a multilevel governance framework ensures the power to incentivize and enforce new policy approaches.

Gas drilling and knowledge flows – the importance of local knowledge

When rural communities become engaged in sustainability actions, they can expand the discussion with the injection of local knowledge. One example is the debate over the new high volume hydro-fracturing techniques for extracting natural gas in New York and Pennsylvania. This case demonstrates the critical importance of co-production of knowledge in yielding a more complete scientific and policy understanding of a complex issue. It also shows the need for a communicative co-production process within a multilevel governing framework where higher authority respects the diversity of interests and local knowledge across the rural landscape.

The Marcellus Shale reserves under New York and Pennsylvania offer the promise of meeting much of the US energy needs for years to come. Geologists estimate the formation may contain up to 489 trillion cubic feet of natural gas (NYSDEC 2012). Natural gas extracted from shale has a smaller carbon footprint than oil or coal (Cathles et al. 2012). New York State views gas drilling as a positive climate change mitigation strategy as well as an opportunity to boost the economically depressed rural upstate region and push New York towards energy self-sufficiency. In 2008 the state legislature updated its compulsory integration law to allow gas companies to drill under private land in spacing units of 640 acres if 60 percent of the acres in that unit are leased by landowners to the gas drilling company (NYSDEC 2008). This was designed to prevent private landowners from holding out and blocking drilling on neighboring property. State leaders perceived drilling as important to energy sustainability, economic development, and equity for rural areas, but the issue turned out to be more complicated.

Pennsylvania pushed forward with drilling while New York continued to study the process and

conduct environmental reviews. Between 2007 to 2010, 1,454 wells were drilled in 33 counties of rural northern Pennsylvania. Estimates of economic impacts suggest between $2 and $5 billion in new revenue, 29,000 construction jobs, and $240 million in state and local tax revenues (Considine 2010). However, early enthusiasm for drilling has been moderated by local concerns over water quality (groundwater contamination and surface stream spills), truck traffic and impacts on road quality, and the negative social and economic impacts on housing and long term employment (estimated at only 2 percent of construction employment) (Christopherson 2011). New York residents have learned from Pennsylvania's experience.

Little understood at the beginning, at least by the public, were the implications for water quality. Safe groundwater is an important public health issue for rural residents, and an economic issue as the region's agricultural industry is based on dairy farming, and cows require clean drinking water. In the hydro-fracturing process, each well uses an estimated one to six million gallons of water mixed with unknown chemicals (the identities are trade secrets) that frees the natural gas from the shale rock. The wastewater must be treated to avoid contamination of streams and neighboring water wells. Local recognition of this issue in New York has led the Conference of Environmental Health Directors (a statewide group of county health officials) to recommend the state ensure that the costs of water testing and treatment are covered by drilling fees (Riha and Rahm 2010). This organization of county health departments – who hold primarily responsibility for responding to water quality complaints – seeks to collaborate with the New York State Department of Health and New York State Department of Environmental Conservation, which are primarily responsible for clean up. If the state would listen to this polycentric network of county health departments, a more appropriate policy would be co-produced.

Wear and tear on rural roads is another example of the local economic impacts not considered initially. Drilling each well requires from 600 to 1,100 truckloads of water – a significant portion of them driving on rural roads, which were not built to handle this traffic load. Even paved roads, which cost up to $100,000 per mile to rebuild, cannot handle this kind of traffic for very long (Randall 2010). This new knowledge has led to recommendations for 'road use agreements' and 'haul route management' – but local governments do not have the power to enter into such agreements without state approval.

A 2013 study found 179 communities had passed restrictive legislation regarding shale gas extraction in New York and 60 had passed legislation in support of drilling (Frickey 2013). The study found

those communities passing restrictive legislation were larger, richer, more highly educated, and located adjacent to metropolitan areas. They also had lower trust in the willingness of higher levels of government to protect their local interests. Indeed, the federal government had specifically exempted shale gas extraction from the Safe Drinking Water Act in 2005 (U.S. EPA 2005).

The top two concerns driving these local actions were water quality and road maintenance. By resorting to land use laws, one of their few strong local powers, these towns have used local legislation to inject their concerns into the debate. So far, the local drilling restrictions have withstood court challenges by gas drilling companies. This approach, if it continues, will establish a patchwork of local rules that make resource extraction inefficient (some drilling companies have already announced that they will pull out of the New York market) and may increase negative externalities, as well as hostilities, between municipalities as some enact tougher standards than others.

These town bans grew out of local public debate. Such strong debate – both pro and con – is forcing more study and bringing more of the conflicting scientific views to light. This is an example of how local engagement can broaden the framing of an issue. The challenge is to ensure that such discourse leads to co-production of knowledge and joint policy action. Absent strong state leadership in a co-production approach, the contentious debate threatens to drag on in an uncoordinated manner that leads local governments to act on their own. In reaction to this movement, the Governor of New York State has proposed a more limited "pilot" approach where drilling will be allowed only in the richest shale deposits and in towns that support the extraction. This may create opportunity for more collaborative learning and policy generation, or it may just be a stop gap political measure that undermines a coordinated approach. New York State is still struggling to figure out how to share power in a multilevel governance framework.

Watershed Protection via a Co-production Approach

Our third example illustrates a cooperative co-production approach, piloted in Michigan and now being pursued by the US Environmental Protection Agency (EPA) in other states. Officials at the EPA decided to "require the support of the regulated community" (U.S. EPA 2003, p. 2) when it sought to broaden watershed protection beyond the point-source, top-down regulation of individual polluters. Federal regulators chose this co-production approach because they believed it would yield more efficient and

innovative solutions needed to make additional improvements in water quality.

In the US, the federal EPA has the authority to regulate discharges into waterways. Traditionally, this has been handled on a pollutant-by-pollutant basis with the agency issuing point-source discharge permits. Agency leaders decided to encourage a local and regional look at pollution across a watershed. EPA recognized watershed-wide protection of water quality as a collective action problem, which should involve a variety of stakeholders and might be better addressed through flexible strategies that allow a more comprehensive and sustainable solution. Administered by state and regional offices, the watershed-wide program involves various stakeholders, such as local governments, residents, and polluters, in an active process to collect information and design effluent reduction strategies that fit particular situations, but still meet national standards (EPA 2003).

One of the reasons the EPA chose the co-production approach to watershed management was its success in the Rouge River Watershed, which began as a pilot project in 1997. The watershed, in southeastern Michigan, consists of four waterways – a 44-mile long main stream and three major branches. The watershed encompasses nearly 450 square miles with more than 1.3 million people in 48 communities. Half of the land is urbanized, including the city of Detroit, and half is rural. Water quality concerns focused at first on the 168 combined sewer overflows that dumped polluted water into the various waterways during heavy rains. Over the course of the project, the issues broadened and various programs were introduced to correct the overflows, eliminate illegal discharges, and strengthen the system of green infrastructure (Garrison and Hobbs 2011).

Communities came together voluntarily in the Rouge River Project as an alternative to imposition by federal courts of a stormwater authority that would direct the river's rehabilitation in a top-down manner (U.S. EPA 2007). Municipalities (who were also the main polluters as owners of the combined sewer overflows), environmental activists, and other citizens brought their local knowledge to multiple working groups and crafted policy solutions suitable to local circumstances. Seven of these advisory groups, one for each major sub-watershed, also included community residents, county agencies, watershed councils, and other stakeholders. A watershed-wide steering committee oversaw the entire project and coordinated the seven advisory groups. The process garnered local support by building accountability within local power structures; it also included broad-based public education. The co-production process recognized the

differences between urban and rural places with allowances made for smaller and rural committees within the watershed, which did not contribute much to the problem, to have less stringent requirements.

Environmentally, the program has been a success (Cave 2003). Pollution from combined sewer overflows has been cut 90 to 100 percent during most rainstorms. Toxic chemicals are no longer a major concern in the river with acceptable levels of health for biological communities throughout the watershed. For the first time in decades, people can consume the fish caught in one lake of the watershed. Salmon now migrate up from the Detroit River to the headwaters of the Rouge River and the number of amphibians has increased. Eventually this co-production watershed protection program was adopted across the State of Michigan and the EPA is now pursuing a similar strategy for watershed protection in other states.

What do these cases teach us about co-production of knowledge and policy? The first two cases illustrate the limits of local action and the need for a multilevel governance framework. While local control over land use policy in the US permits local experimentation and voice, it undermines regional coordination and is subject to severe capacity constraints and problems with externality spillovers, especially in rural areas. This suggests that while co-production of knowledge and policy is necessary to ensure upward information flows and local support for policy adoption in rural areas, local control is not sufficient to address commons issues that cross jurisdictional boundaries, like climate change. The second example concerning natural gas in New York also demonstrates the limits of top-down regulation and the need for local knowledge to shape policy for coordination, knowledge exchange and sanctioning power that can enhance polycentric local action. The promise of a multilevel governance framework is presented in the Rouge River case where federal, state and local actors coordinate in a network approach that respects local knowledge and diversity but sets a common framework of goals and standards upon which all parties can act in a coordinated manner. Our goal is not to present the precise mechanisms by which such a multilevel system can be achieved, but rather to demonstrate that true co-production makes local governments partners in policy, rather than simply agents of implementation.

5. Conclusion

US rural communities face unique challenges in addressing climate change. The fragmented nature of local government, local capacity constraints, and the inability to address cross-jurisdictional externalities

threatens the efficacy of a polycentric approach to climate change policy. And yet the absence of national policy on climate change leaves local solutions as the only alternative. In this paper we present an approach that preserves the benefits of polycentrism in the co-production of knowledge and policy that is so critical to rural acceptance, innovation, and responsiveness to the unique nature of rural problems, while ensuring that externalities and capacity constraints are addressed. That solution is the articulation of a multilevel governance framework that creates bidirectional knowledge flows and shares power for sanctioning across actors in the environmental governance network. Unlike in Europe where some national governments have taken up the cause of climate change, the U.S. lacks an overarching governance framework. Rural communities and small towns represent the majority of the American landscape and thus make broadening the drive for local climate action beyond large urban areas a critical challenge.

In this article we call for a co-production approach to knowledge generation and policy creation. This strategy is crucial for climate change where systems are complex, knowledge evolves rapidly, and buy-in from multiple stakeholders is required. Such an approach ties local knowledge from diverse rural areas to expert climate knowledge and centrally coordinated goals. We have explored issues of power, situational context, and framing, as well as coordination and the challenge of local enforcement across rural areas. Our examples show that framing the issue in a broader context and allowing co-production of knowledge and policy may facilitate more rural community attention to environmental issues. This offers some small promise for future positive movement on climate change. However our study also demonstrates the critical importance of a multilevel governance framework.

Designing the organizational architecture for policy design and implementation requires attention both to the positive power of network governance and to it limitations. Polycentric environmental governance networks need coordination and members need both capacity and power to sanction. The challenge will be to design such co-production systems so that power is shared and the voice and concerns of rural communities are included.

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