Journal of Public Administration Research and Theory Advance Access published November 4, 2007

Local Policy Networks and Agricultural Watershed Management

Mark Lubell
University of California, Davis
Allan Fulton
UC Cooperative Extension

ABSTRACT

This article emphasizes the critical role of local policy networks for the implementation of agricultural watershed management and the adoption of environmental best management practices. Local networks facilitate diffusion of innovations, the development of social capital, and cultural change. All of these elements are essential for the ability of watershed management programs to successfully solve the water quality collective action problems caused by agricultural nonpoint source pollution. Analyses of survey data from 408 orchard growers in California's Sacramento River watershed demonstrate that exposure to policy networks substantially increases the probability of adopting environmental practices. These findings have important implications for public administration and policies where implementation depends on widespread cooperation and the development of networks with public agencies.

The main goal of this article is to analyze the role of local policy networks for the implementation of agricultural watershed management. Policy networks consist of interconnected actors in a policy subsystem who communicate information about policy through some social connection (Mintrom and Vergari 1998; Rogers 2003). Agricultural watershed management is designed to reduce water quality problems associated with agricultural production, and successful implementation requires widespread cooperation.

We are specifically interested in testing the hypothesis that policy networks between agricultural producers and local agencies/organizations increase the rate at which producers adopt environmental "best management practices" (BMP) for improving water quality. Within the literature on agro-environmental policy, BMP commonly refers to agricultural practices designed to alleviate problems associated with nonpoint source pollution from agricultural runoff. For example, this article analyzes orchard growers' use of vegetative filter strips to control irrigation and stormwater runoff into waterways. BMP adoption, which is usually one of the main implementation goals of watershed management, entails a challenging problem in cooperation. Because individual producers cannot make a large difference in overall water quality and nonpoint source pollution is

Address correspondence to the author at mnlubell@ucdavis.edu.

doi:10.1093/jopart/mum031

costly to monitor, each producer has an incentive to free ride on the BMP efforts of others. Cooperating producers risk investing in BMP that have little payoff because others are not investing, and they generally want to avoid the "sucker's" payoff (Axelrod 1984) where their efforts are wasted because no other producers contribute.

Our investigation of the link between policy networks and BMP implementation is directly relevant to public administration and policy theory for several reasons. First, watershed management programs are an important example of collaborative policy designed to encourage cooperation among multiple stakeholders. These programs have emerged all over the United States and internationally in the last two decades, and a growing body of research is devoted to analyzing the effectiveness of these policies and the role of networks in promoting cooperation (Bosch, Cook, and Fuglie 1995; Lubell et al. 2002; Marshall 2005; Sabatier et al. 2005; Schneider et al. 2003).

Second, at the same time that collaborative watershed management is becoming more prevalent, public administrators at the state and Federal level may ironically be dismantling the local policy networks that are crucial for implementation. One example is local agricultural outreach programs, which are important components of policy networks that in many states have been developing for over a century. The two main Federal funding sources for land grant university agricultural outreach programs—Agriculture Experiment Stations (1887 Hatch Act) and the Cooperative Extension System (1914 Smith-Lever Act)—only increased by 4.8% and 1.6%, respectively, from 1996 to 2006. Although the full impact of these flat budgets depends on state and local decisions, they have contributed to significant decreases in local policy networks in several important agricultural states. From 2002 to 2004, California lost 152 county Cooperative Extension positions in 20 different counties. Three of the top states receiving Federal funding also report losses in Cooperative Extension staff—Texas reports losing 40 positions (7% decrease) in the last 15 years, North Carolina has lost 112 positions since 2000 (12% decrease), and Pennsylvania has lost 161 permanent positions in their College of Agricultural Sciences since 2002.[1] Although Cooperative Extension positions are not the only actors involved, in general public managers need to be cognizant of how their decisions can weaken or strengthen these networks.

Lastly, our study focuses on a nationally significant example of agricultural watershed management occurring in California's Sacramento River watershed called the Sacramento Valley Water Quality Coalition (SVWQC). The SVWQC covers approximately 2.1 million of irrigated agriculture in a 321-mile long river corridor—the entire Northern half of California's huge, ecologically significant, and economically vital Central Valley. The SVWQC is one regional component of the first statewide attempt to manage agricultural water quality. The geographic scope of the program, number of landowners involved, and involvement of state environmental agencies makes the SVWQC one of the most comprehensive programs in the nation.

In the next section, we outline three ways in which policy networks are crucial to implementation of agricultural watershed management. Much of this discussion traces the

---

[1] These figures come from personal communications in 2005 with relevant budget officers in each state; the exact numbers may have changed since that time and also depend on how different positions are defined by each state. The figures from Pennsylvania include educator positions at the Penn State campus and not just County Extension. According to Pennsylvania officials, they have tried to use local funding sources to make up for losses in state and Federal funding, so it is not clear if there was a net loss in local positions. Pennsylvania's efforts show how funding can stress local networks and how government can take steps to reinforce local networks.

evolution of the idea of policy networks from classical diffusion of innovation models to modern theories of social network analysis (Burt 1992; Scott 2000; Wasserman and Faust 1994; Watts 1999), social capital (Coleman 1990; Ostrom 1994; Putnam 2000), and cultural evolution (Henrich 2001; Richerson and Boyd 2005). We next discuss awareness, environmental values, and farm structure as additional sets of factors influencing BMP adoption. We then describe the SVWQC in more detail, followed by our research methods and analysis. The data come from a mail survey of 408 orchard growers involved with the SVWQC. The conclusion discusses broader implications for public administration in the context of policies where implementation depends on widespread cooperation and behavioral change.

POLICY NETWORKS AND AGRICULTURAL WATERSHED MANAGEMENT: THREE PATHWAYS TO POLICY IMPLEMENTATION

The concept of policy networks has evolved through three traditions of research: (1) the classical diffusion of innovation model and its offspring, (2) theories of social capital, and (3) theories of cultural evolution. We are most interested in the relevance of these theories to individual-level behavior, although the concept of policy networks has important implications for organizational and government decision making as well (Berry FS and Berry WD 1992). The purpose of the discussion is to provide a theoretical basis for our central hypothesis: orchard growers' exposure to local policy networks is one of the most important catalysts for the adoption of environmental BMP.

We must be clear about the level of theoretical development represented in this analysis. Although each of the perspectives below supports our central hypothesis, the theories are not mature enough to provide competing hypotheses from each framework or to identify the conditions under which one function of local policy networks is more important than another. Furthermore, each of the theoretical perspectives suggests more detailed hypotheses that are not tested here, for example, more sophisticated measures of network structures (e.g., network centrality) or specific types of social learning strategies (e.g., conformity). The contribution of this analysis is to identify the most relevant theoretical perspectives for understanding the role of policy networks, with the hope of setting the stage for later research into more detailed mechanisms. However, the theory here is well developed enough to establish the practical relevance of networks to local policy implementation and how the decisions of public managers can affect network strength.

Policy Networks in Classical Diffusion Models

Classical diffusion of innovation models emphasize the importance of policy networks as part of "the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers 2003)." Based partly on information derived from policy networks, each member of a social system evaluates the costs and benefits of a particular innovation and then adopts that innovation if benefits outweigh costs. However, not all members of a social system are initially aware of the existence of an innovation or certain of the benefits. Hence, the proportion of the population adopting an innovation over time has the classic S-shaped signature, with few adopters at first, an accelerating proportion in the middle, and saturation at the end. The overall shape of this curve can vary substantially depending on the individual and social learning processes used by members of the social system (Henrich 2001).

In the context of agricultural watershed management, policy networks include agricultural producers, government agencies, and other local organizations as members of the social system. These networks spread information about the existence and effectiveness of different types of BMP, the existence of water quality issues and polices, and the decisions and viewpoints of other producers. Interestingly, some of the earliest and best research applying classical diffusion models to BMP found networks to be relatively unimportant (Napier and Camboni 1988; Napier, Camboni, and Thraen 1986; Napier, Thraen, and McClaskie 1988; Napier et al. 1984). These pessimistic findings encouraged Napier and his colleagues to question the utility of diffusion models and the effectiveness of traditional agricultural outreach programs to cause substantial changes in environmental practices (Napier and Tucker 2001; Napier, Tucker, and McCarter 2000).

Napier et al. offer explanations throughout these studies for the weakness of diffusion models. A central theme of these explanations is that adoption decisions about environmental BMP are somehow different from those used to make decisions about other agricultural practices (Napier and Tucker 2001; Napier, Tucker, and McCarter 2000). A crucial characteristic of classic diffusion research is that the innovations studied had clear and known benefits for individual producers. BMP, on the other hand, often entail short-term costs for a producer, whereas the benefits are often long-term and uncertain. The uncertainty is exacerbated by the collective action problems of BMP adoption because the environmental benefits depend partly on the decisions of other producers when they share a common-pool resource such as a watershed.

More recently, advances in social network analysis (Scott 2000; Wasserman and Faust 1994; Watts 1999) have reinvigorated the role of networks by showing how adoption decisions depend on the overall structure of the network and the position of a particular individual within a network. Foster and Rosenzweig (1995) use a household panel study of farmers in India to show that farmers with experienced neighbors tend to use more high-yield seeds and be more profitable. Valente (1996) examines adoption thresholds, which specify the proportion of adopters in social network needed for an individual to adopt an innovation. Chiffoleau (2005) provides evidence that networks linking individuals with specific knowledge to broader professional communities influenced the development of environmentally friendly viticulture in France. Conley and Udry (2001) present evidence that farmers in Ghana learn from relatively sparse social networks and use a mathematical model to explore the implications of network structures. These studies suggest that the importance of networks varies across different situations depending on key network variables, but there is not yet a well-accepted general theory that identifies which network variables are the most important.

Policy Networks as Social Capital

Policy networks also represent an investment in social capital. Social capital consists of networks of civic engagement, norms of reciprocity, and trust (Ostrom 1994; Putnam 2000). Social capital is particularly important in the case of collective action problems where the costs and benefits of behavior are influenced by the decisions of multiple other actors in the social system. Cooperation in these situations depends on the development of reciprocal strategies, where actors are more likely to cooperate if they believe others in the group will also cooperate.

The social capital perspective suggests that policy networks should have a very large influence precisely because the benefits of BMP adoption depend heavily on cooperation from other producers, as well as government and non-profit organizations involved with delivering information and cost-share programs. Over time, networks consisting of face-to-face interactions between multiple actors can enable the evolution of reciprocal strategies and the spread of reputations for trustworthiness.

It is important to note that the social capital associated with local agricultural organizations has been developing for many years. Social capital is difficult to create; it accrues over time in the context of repeated interactions across multiple different arenas. The social capital developed in the context of these other interactions is then used as a basis for solving water quality problems. For example, many producers interact with the UC Cooperative Extension to learn more about agricultural production techniques. That is why decision makers at higher levels of the Federal system must partner with local organizations to implement policy and also recognize that it is easy to destroy this social capital by removing key nodes in the network.

Policy Networks and Cultural Change

Policy networks can also be pathways for cultural change and more broadly cultural evolution (Henrich 2001; Richerson and Boyd 2005). Theories of cultural evolution posit social learning from others as the key mechanism of cultural change. Social learning occurs when one member of the social system makes decisions on the basis of the behavior of another member or members of the group. Models of cultural evolution consider a wide range of social learning mechanisms, and the exact pattern of cultural change depends on the structure of the mechanism under consideration. For example, people may imitate the most prestigious or successful individuals, known political leaders, or the majority of individuals. Social learning may also involve processes of persuasion, where other people in the group actually change the preferences of the individual.

Viewing policy networks as pathways to cultural change is vital in an era when agricultural communities are increasingly being asked to consider the environmental implications of their behaviors. Part of this change involves new government policies that reward environmentally sustainable or punish unsustainable behavior. But just like with any cultural change, these policies are more likely to succeed when accompanied by widespread acceptance of new behaviors and norms throughout a community.

Theories of cultural evolution would focus on the role of social learning and policy networks in gaining acceptance of environmental concerns within agriculture. Many producers will look to local agricultural leaders for cues as to which BMP are most effective and whether or not to support a particular policy program. The identity of the most successful and innovative producers is generally well known by the local agricultural community. It is important for local agencies to develop networks with these opinion leaders in order to achieve broad acceptance of new policies.

Other Influences on BMP Adoption: Awareness, Environmental Values, and Farm Structure

Each of the theoretical perspectives above suggests that policy networks will have a strong influence on BMP adoption, but other producer characteristics should be considered. Earlier research on diffusion models has shown that awareness of environmental problems and practices increases the probability of adopting those practices (Napier, Thraen, and McClaskie 1988). Feather and Amacher (1994) conclude that awareness of practices decreases uncertainty about innovations and that educational programs can increase awareness. Hence, we hypothesize that growers who are aware that pesticides have been detected in the Sacramento River, and have been informed about BMP, are more likely to adopt practices.

Many studies of environmental behavior have demonstrated that environmental values are important predictors of many different types of environmental behaviors (Karp 1996; Stern et al. 1995, 1999). Environmental BMP are a specific type of environmental behavior, and thus environmental values may have a similar positive effect. If environmentally minded growers adopt BMP, and also build networks to facilitate adoption, then there could be a spurious correlation between network exposure and BMP frequency.

Later applications of diffusion models to agricultural and environmental practices argued that operation and operator characteristics will influence the net benefits of innovation. These "farm structure" models hypothesize that larger and more economically profitable operations have more resources for innovation. The net benefits of innovation are also higher for operations or crop types that are more complex, or which are more sensitive to variations in soil/water characteristics, where productivity depends on experimenting with many different techniques. Operators with more experience or education will have more knowledge to utilize when making innovation decisions. The analyses below control for awareness, environmental values, and farm structure variables to isolate the effects of policy networks.

AGRICULTURAL WATERSHED MANAGEMENT IN THE SACRAMENTO RIVER VALLEY

Agricultural water policy in California recently underwent a dramatic change when state legislation required the Regional Water Quality Control Boards to adopt new "Conditional Waivers" (as opposed to a discharge permit/requirement) for managing agricultural discharges. The Regional Boards are the main implementation agencies for the California state water quality program (Porter-Cologne Water Quality Control Act of 1969), and from 1982 to 2002, agricultural sources were operating under Conditional Waivers that had minimal regulatory requirements.

The main focus of this article is on the Central Valley Regional Board, which adopted a new Conditional Waiver on January 1, 2003. One compliance option under the new program is for agricultural producers to join watershed management Coalitions that work together to conduct water quality monitoring and to implement water quality management plans. Other compliance options involve obtaining some type of individual permit from the Regional Board. The vast majority of producers in the Sacramento Valley have opted to join the regional Coalition, which is called the SVWQC. The SVWQC is preferred because it allows sharing costs of monitoring, facilitates local oversight, takes advantage of local knowledge, and is less intrusive on individuals. The SVWQC also focuses on the watershed, considers the cumulative effects from multiple operations, and integrates some of the elements of collaborative policy at the local level. But the Waiver program is best described as a blending of collaborative and regulatory institutions, because all agricultural producers must choose one of the available compliance options.

The main goal of the SVWQC is to identify any existing nonpoint source pollution resulting from farming practices and then encourage the implementation of BMP to solve these problems. At the time of this study, the program had not advanced enough to actually require implementation of new BMP, although voluntary implementation was encouraged. In other words, there were no formal incentives for BMP adoption—rewards or punishments—embodied in the program. However, producers had been exposed to the idea of water quality BMP through many other programs with incentives (e.g., US Department of Agriculture cost-share programs), and the Regional Board has already started to use light enforcement measures (e.g., warning letters) against non-compliant producers.

The critical role of policy networks is illustrated by the SVWQC's nested watershed approach, which divides the larger watershed into 10 subwatershed groups. The subwatershed groups are in charge of on-the-ground implementation, encouraging producers to enroll in the program, participate in management activities, and adopt BMP. The subwatershed groups are typically headquartered with local organizations such as the County Agricultural Commissioner, County Farm Bureau, or an established local watershed group. The subwatershed leadership collaborates with many other local stakeholders such as Resource Conservation Districts, UC Cooperative Extension, and the Natural Resource Conservation Service. The exact structure of the partnerships is different in each subwatershed, reflecting the unique configuration of networks, political interests, and expertise in each area. Regional coordination among the subwatershed groups is achieved by three main organizations: Northern California Water Association, Duck's Unlimited, and the Coalition for Urban Rural Environmental Stewardship. As will be demonstrated in the following analysis, these local and regional agencies are key nodes in the policy network.

RESEARCH METHODS AND ANALYSIS

The mail survey was delivered during the winter of 2004–05 to a total of 1,285 orchard growers in seven counties in California's Sacramento Valley. Although there is a huge diversity of crop types in the Sacramento Valley, orchards are a profitable crop with important influences on water quality. A total of 408 of growers responded to the survey (32% response rate). The sample of orchard growers was based on lists of all prune, peach, walnut, and almond growers as identified by a local agricultural consultant. The sample is thus close to a complete census of these crop types in the seven-county region, and the whole sample received the survey. The survey was administered using Dillman's (2000) total design method, with an introduction letter followed up by two waves of survey packages and reminder postcards.

Each respondent could indicate owning prunes, peaches, walnuts, or almonds and thus could report more than one type of orchard. The 398 orchard respondents who provided crop information reported a total of 608 orchards. Of these respondents, 65% owned one type of orchard, 24% owned two types, 5% owned three types, and 6% owned four types. Of the total 608 orchards, 28% were almonds, 9.5% were peaches, 19% were prunes, and 43% were walnuts. Sixty-four percent of the growers report belonging to an agricultural cooperative or commodity group, and they have spent an average of 34 years in the agricultural business.

Some of the sample characteristics can be compared to 2002 Agricultural Census (Ag Census) figures from the seven-county region to get a better sense of the representativeness of the sample. However, publicly available Ag Census numbers combine orchards with other types of agricultural operations. The Ag Census reports an average operation size of 371 acres, whereas our respondents report an average size of 487 acres.[2] In terms of economics, the Ag Census reports 63% of the operations with annual sales less than $49,000, 10% with $50,000–99,999, and 27% with over $100,000. The study respondents

---

[2] The size statistics reported on our survey refer to all land leased and owned, including orchard and non-orchard acres.

report 39% with less than $49,000 in gross farm revenue, 16% with $50,000–99,999, and 45% with over $100,000. The difference in distribution of revenue between the Ag Census and this survey is attributable to the fact that gross farm revenue as measured by the survey includes sales plus additional income such as rental payments and also that orchard crops also tend to have higher prices than other commodities.

In terms of operator characteristics, 83% (Ag Census = 88%) of the operators in our sample are white and 5% female (Ag Census = 30%). While the race statistics are very similar, our sample has substantially more male operators than the Ag Census. The gender difference occurs because in 2002, the Ag Census began collecting demographic information for all operators on a particular farm, not just the principal operator. In contrast, only the principal operators are identified in our sample, and the gender distribution in our survey would occur if most principal operators were male.

Although the results of this analysis must be interpreted in light of any potential sample biases, we do not believe these biases are severe enough to damage the value of our findings. The most significant potential problem is that larger farms that generate more revenue are more likely to be innovators. If the sample is skewed toward more innovators, then the frequency of BMP implementation discussed in the next section is probably inflated. This type of bias is less likely to influence estimates of the relationships between our independent and dependent variables, although the correlations between our measures of size and farm revenue would be reduced. Hence, we expect most of our findings about the forces influencing adoption behavior can be safely generalized to the broader population of orchard growers in the Sacramento River watershed.

Dependent Variable Construction: BMP for Improving Water Quality

The survey contained an extensive battery of questions about BMP identified by local agricultural experts as effective for reducing the impacts of agricultural production on water quality. We divided these BMP into three categories: conventional pest management, alternative pest management, and runoff controls. We then identified how many specific practices a grower had within each category; table 1 shows the frequency of use.

The conventional pest management category contains six practices that are likely to reduce the total amount of pesticides entering the environment. Some of these practices also have significant economic benefits for the grower because they reduce the amount of pesticide required and thus production costs. Furthermore, growers are more experienced with conventional pesticide management practices. Hence, it is no surprise that the highest frequency of adoption occurs in the conventional pest management category.

The alternative pest management category contains three types of practices that potentially reduce agricultural pests without using pesticides. Although there are clear environmental benefits to alternative pest management practices, there is no consensus about their effectiveness at controlling pests or their ability to substitute for conventional pest management practices (Grant et al. 2004; Pickel, Grant, and Welter 2005). Hence, alternative pest management practices have the lowest frequency in the survey.

The runoff control category contains two practices designed to reduce the total amount of water leaving an orchard from irrigation drainage and possibly reduce the concentration of pesticide and nutrient contaminants running off from orchards (Fulton, Krueger, and Little 2001; Zalom et al. 2002). These practices may also have direct benefits for the farm, for example, by providing additional soil nutrients or habitat for beneficial

Table 1
Percentage of Farmers Using Water Quality Management Practices

	Percentage of Farmers Using Each Practice
Conventional pest management practices	
Base spray timing on weather/wind	88.48
Dispose of rinsate by mixing with water and reapplying to orchard	80.88
Pesticide sprayers calibrated before every application or more than once per year	61.52
Maintain setback/buffer zones when spraying	46.32
Check droplet/nozzle size on sprayer	39.46
Dormant sprays applied to treat problem instead of preventative[a]	10.78
Alternative pest management practices	
Provided beneficial insect habitat	30.88
Used pheromone mating disruption	17.65
Released beneficial insects in past 5 years	10.78
Runoff control practices	
Filter strip between orchard and waterway[a]	50.25
Use resident/planted vegetation as cover crop	36.52

[a] Some respondents skipped these questions because they indicated not using dormant sprays every year or not having stormwater runoff. To avoid eliminating these observations from the analysis, we coded the skipped questions as zero. This does create some measurement error because farmers who skip the questions never have the opportunity to indicate they are using that specific strategy. Of those farmers who did not skip the questions, 22.3% use dormant spray only for treating problems and 88.4% use filter strips. The results of the analyses are not substantively different if those two practices are removed from the scales.

insects. Runoff controls are between conventional pest management and alternative pest management in terms of frequency of use.

The analysis below uses four different scales to measure the level of BMP adoption by each grower. The *overall practices* scale sums all 11 practices from each of the categories and ranges between 0 and 11 with a mean of 4.7 practices. The other scales sum the practices from a particular category. The *conventional pest management* scale ranges from 0 to 6 with a mean of 3.2, the *alternative pest management* scale ranges from 0 to 3 with a mean of .59, and the *runoff control* practices scale ranges from 0 to 2 with a mean of .87. The ordered nature of these variables follows the tradition of BMP studies that construct some type of scale to measure adoption frequency, as well as real-world BMP programs that use adoption frequency as a measure of success or even regulatory compliance under the assumption of a positive correlation between adoption frequency and environmental benefits. We will discuss later how the statistical model accounts for the ordered and discrete nature of these scales.

Independent Variable Construction: Policy Networks, Awareness, Environmental Values, and Farm Structure

We use two different measures of exposure to local policy networks. *Policy network contacts* is a count of the number of agricultural agencies contacted by the producers regarding water quality issues at least once in 2004, from a list of 11 mostly local agencies and non-profit organizations including other farm operations. The network contact variable is a direct measure of interaction between growers and elements of the policy network that have traditionally delivered services and knowledge to agricultural producers. However, the survey question wording is deliberately designed to focus on water quality management rather than some of the other issues for which these organizations may have been contacted. Figure 1 demonstrates how these 11 organizations have very high levels of trust and contact relative to the regulatory agencies and regional organizers.[3] These contact patterns have developed over many years and in many different contexts and provide a reservoir of social capital for use in watershed management.

Watershed management activities is a count of the number of watershed management activities in which the grower has participated from a list of five voluntary activities (read brochures, attend meetings, speak with representatives, committee member, training classes) offered by the SVWQC. Participation in these watershed management activities indicates exposure to members of the policy network and also information about water quality problems and BMP.

The analysis uses two measures of awareness. *Pesticide awareness* is a [0, 1] indicator variable that equals one if the grower reports knowing that pesticides have been detected in local waterways during the dormant spray season. *Practices awareness* is a [0, 1] indicator variable that equals one if the grower reports being informed of management practices that reduce the potential for pesticides moving from orchards into waterways. The *environmental values* scale averages two questions (seven-point Likert scales; 1 = disagree, 7 = agree) about the appropriate balance between economic development and environmental protection, with higher values coded as pro-environment.

Farm structure variables include measures of crop size/patterns and operation income. The variables *almond acres, peach acres, prune acres, and walnut acres* all measure the number of acres (in hundreds) devoted to that particular commodity on a particular operation. Operations with multiple orchards will have positive acres for more than one commodity, whereas operations with only one orchard will have positive acres for only a single commodity type. The acreage variables are separated into different commodity groups in order to measure farm size but also to control for any possible differences across orchard types in terms of pesticide use, other input costs (e.g., water), and the demands for more or different types of innovations.[4] For example, different types of orchard crops host specific insect pests and therefore the need for and choices made among management practices may vary among these orchard crops. *Number of orchard types* is a count ranging between 0 and 4 for the total number of orchard types on the operation.[5] Operations with more types of orchards are more complex, which may provide greater incentives for innovation. *Gross orchard income* is an eight-category variable that measures different levels of annual income (sales, rent payments, government payments), ranging from less than $49,000 to $1 million or above.

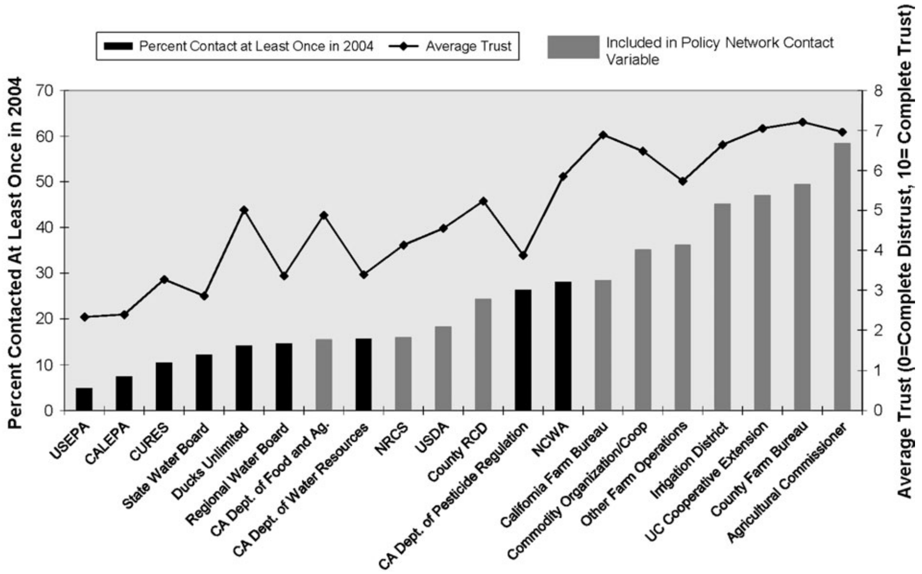
---

[3] The data for figure 1 are from all 1,211 respondents to a broader survey of agricultural producers, including the 408 orchard grower respondents who are analyzed in the subsequent models. The subsequent models focus only on the orchard growers because we have management practices data for only that subset of producers. However, the policies focus on all farmers in the Central Valley so figure 1 displays the structure of policy networks from the entire set of respondents.

[4] We do not have exact data on specific water or pesticide uses for each operation; therefore, we cannot directly estimate the relationship between input costs and BMP adoption. However, we believe our farm structure variables are adequate to control for these economic differences at a broad level, which allows us to focus on policy network variables that are the central theoretical interest. Further research with more detailed operation-level data is needed to better understand the more nuanced relationships between farm structure variables and BMP adoption.

[5] The zero coding on this variable is for growers (four in the sample) that currently have no orchards at all or did not provide information on their orchard acreage. Analyses excluding these growers do not change results.

Figure 1
Trust and Contact with Water Quality Management Organizations



Questions: Below is a list of organizations (or types of organizations) that have been active in the Sacramento River watershed in water quality management. In the last year, how frequently did you speak with each of the organizations-- daily, weekly, monthly, annually, none? Please indicate your level of trust for each organization by entering a number between 0 (complete distrust) and 10 (complete trust).

Operator characteristics include *years in agriculture* (raw number of years) and *education* measured in seven ordered categories (no high school through advanced degree). Years in agriculture could have two different effects on the probability of innovation. There would be a positive effect if growers use their experience to try new things, but there would be a negative effect if older growers tend to resist the introduction of new techniques. It is possible that these effects could cancel out. However, in general, we expect better-educated farmers to have more knowledge about innovative techniques and thus higher probabilities of BMP adoption.

Ordered Probit Models for BMP Adoption

The dominant tradition in the BMP adoption literature is to use linear regression on some type of additive or weighted index of BMP frequency (e.g., Greene 2000; Napier, Tucker, and McCarter 2000; Valentin, Bernardo, and Kastens 2004). However, the ordinal structure of most BMP scales generally does not meet the assumptions of the linear regression model (Greene 2000; Long 1997).[6] Despite these problems, there are few examples of using alternative statistical models to estimate adoption frequency or timing (Fuglie and Kascak 2001; Napier, Thraen, and McClaskie 1988). However, nonlinear models have been used in the more general policy innovation literature (Berry FS and Berry WD 1990, 1992)

---

[6] Although the weighted scales often produce numbers that look more like continuous variables, there is also the additional problem of being uncertain what the correct weights are. Even when expert judgment is used to decide the appropriate weights, there is always some arbitrariness to that decision.

To avoid the problems of using linear regression, we use ordered probit models to estimate the effect of the independent variables on the probability of adopting a certain number of BMP practices. The assumptions of ordered probit models are more appropriate for the ordinal structure of the dependent variables. Ordered probit models have the additional benefit of estimating probabilities, which allows a nonlinear estimation of the innovativeness of individuals within the population. These probabilities replicate the S-shaped curves often found in traditional diffusion studies, but for cross-sectional data.

Ordered probit models are derived from a measurement model in which some latent variable y^* ranging from $-\infty$ to $+\infty$ is mapped into an observed ordinal variable y, which has m ordered categories. For our analysis, y^* measures the underlying innovativeness of a particular grower, and y is the different number of observed practices for the various scales (e.g., 0–11 for the overall practices scale). The ordinal variable y is observed as a function of y^* according to the following measurement equation:

$$y_i = m \quad \text{if } \tau_{m-1} \leq y_i{}^* < \tau_m \ \text{ for } m = 1 \text{ to } J. \tag{1}$$

The τ's are called thresholds and define the intervals on the latent variable where a certain number of practices will be observed based on the estimated level of innovativeness for a particular grower.

The level of innovativeness is then related to the independent variables of the analysis using the following equation (called the structural model):

$$y_i{}^* = \mathbf{x}_i \boldsymbol{\beta} + \varepsilon_i. \tag{2}$$

In the structural model, $\mathbf{x}_i$ is a vector of observations on the independent variables and $\boldsymbol{\beta}$ is a vector of structural coefficients that relate each independent variable to the latent dependent variable. Based on the assumption of normally distributed error terms with fixed variance, maximum likelihood techniques are used to estimate the thresholds and the structural coefficients. For each grower, this provides an estimate of the level of innovativeness (y^*), which in turn provides a prediction of the probability of observing a certain number of practices. There is always some positive probability of observing any number of practices for a given level of innovativeness, but the probabilities change as a function of y^*. These probabilities will be more clearly illustrated in the analysis results below.

Analysis Results: Policy Networks Matter

Table 2 reports the results of four ordered probit models estimated for the overall practices scale and each of the three subscales. The first thing to observe is that the ordered probit models provide a significant fit to the data in all cases (likelihood ratio tests) and explain a non-trivial amount of the variance in BMP adoption probabilities (McKelvey and Zavonia R^2). However, the models certainly do not explain all of the variance, which is to be expected in the case of survey data that often has random measurement error. Also, more detailed information about farm structure and the constraints on implementing specific types of BMP may improve the fit of the models. Overall, the model fit and control variables are adequate to draw some conclusions about the network variables, which are the central theoretical focus of this article.

The parameter estimates ($\boldsymbol{\beta}$ in equation 2) in table 2 provide a first test of the main hypotheses. The important influence of policy networks is demonstrated by the positive and significant coefficients for both network exposure variables in the overall practices and conventional pest management models. The diffusion contact variable is significant in the

Table 2
Ordered Probit Models of Orchard Practices Scales

	Overall Practices Scale	Conventional Pest Management Practices	Alternative Pest Management Practices	Runoff Control Practices
Farm operation characteristics				
Almond acres (100s)	−.002 (.031)	−.003 (.031)	−.035 (.036)	.034 (.036)
Peach acres (100s)	−.333 (.230)	−.335 (.234)	.031 (.254)	−.212 (.256)
Prune acres (100s)	−.018 (.071)	−.041 (.073)	−.111 (.088)	.163 (.082)**
Walnut acres (100s)	.115 (.038)**	.077 (.039)**	.094 (.040)**	.052 (.042)
Number of orchard types	.198 (.085)**	.190 (.087)**	.096 (.097)	.041 (.094)
Gross farm income	.020 (.035)	−.007 (.036)	.040 (.039)	.022 (.040)
Awareness				
Pesticide awareness	.378 (.136)**	.265 (.138)**	.311 (.157)**	.246 (.151)*
Practices awareness	.361 (.166)**	.494 (.169)**	.195 (.198)	−.202 (.184)
Farm operator characteristics				
Environmental values	.024 (.041)	.072 (.04)*	−.009 (.048)	−.060 (.046)
Years in agriculture	.003 (.004)	.001 (.004)	.001 (.005)	.0004 (.0006)
Education	.020 (.035)	−.024 (.036)	.020 (.041)	.046 (.038)
Network exposure				
Number of watershed management activities	.128 (.051)**	.110 (.051)**	.057 (.057)	.079 (.057)
Number of policy network contacts	.068 (.026)**	.057 (.026)**	.029 (.030)	.050 (.028)*
Model fit statistics				
Log likelihood	−604.25	−489.77	−300.40	−310.30
Likelihood ratio test	$\chi^2 = 98.74$**	$\chi^2 = 66.48$**	$\chi^2 = 35.31$**	$\chi^2 = 45.59$**
McKelvey and Zavonia's R^2	.28	.21	.14	.17
Probability distribution thresholds				
Threshold 1	−1.18	−1.21	1.02	.62
Threshold 2	−.64	−.75	2.23	1.86
Threshold 3	−.08	−.01	2.92	—
Threshold 4	.51	.79	—	—
Threshold 5	1.09	1.61	—	—
Threshold 6	1.64	2.84	—	—
Threshold 7	2.30	—	—	—
Threshold 8	2.95	—	—	—
Threshold 9	3.30	—	—	—
Threshold 10	4.02	—	—	—
Threshold 11	4.37	—	—	—

Note: Table entries are unstandardized parameter estimates from ordered probit models. Two-tailed z-tests of null hypothesis that parameter = 0: $^{**}p < .05$; $^{*}p < .10$, $N = 310$ for all models due to missing data on farm structure, awareness, and environmental values variables. If farm structure and environmental values variables are dropped from analysis, then both network exposure variables are significant at $p < .05$ in runoff control model.

runoff control practices model, and the watershed management activity variable is significant if the environmental values variable is dropped from the model (N is higher because of missing data in the values variable). The network exposure variables are not significant in the alternative pest management model. The awareness variables are also significant and positive in nearly every model, with pesticide awareness being more consistent. Of the farm structure variables, walnut orchard acres and number of orchard types have significant effects on all but runoff control practices. This suggests that larger and more complex operations tend to have higher levels of innovation, especially when walnuts are one of the commodities being produced.

Although further research is needed to be certain, there are some differences between walnuts and other crops that may reduce the costs of implementing BMP for walnut orchards. Walnuts are traditionally grown on the high-quality riparian soils near the Sacramento River, where the existence of natural vegetated filter strips reduces the amount of effort required from grower. Walnuts bloom later in the year and are thus less susceptible to frost and economic pests and more tolerant to deviations from proven conventional techniques. Conservation organizations also tend to focus their efforts first on riparian land; so walnut growers may be more exposed to conservation ideas. Other orchards that bloom earlier, in particular almonds, also must consider the negative effects of cover crops on air temperature and related risks to frost injury, which may make growers reluctant to implement that particular practice.

These basic parameter estimates are best interpreted by investigating the predicted probabilities of adopting different numbers of practices. Table 3 displays observed percentages of each number of practices, as well as the average predicted probability of that number of practices as estimated from the ordered probit models. For example, 17.65% of the growers have four practices on the overall practices scale (table 3, column 2), with the average predicted probability from the model being .176 (table 3, column 3). Multiplying the average predicted probability by 100 provides the expected percentage in the population, which closely matches the observed percentage.

Figure 2 begins to assess the importance of policy networks by plotting the cumulative observed frequencies for the overall practices scale alongside the cumulative predicted frequency and the predicted frequencies for a population with minimum policy network exposure and maximum policy network exposure. Exposure is defined as the combined influence of policy network contacts and watershed management activities.[7] Figure 2 shows how the models reproduce the family of S-shaped distributions typical of diffusion of innovation models, even though we are not measuring time until adoption. Rather, by measuring the number of innovations, we are assuming each practice takes some time and costs to adopt, and thus growers with more practices are higher on the innovation curve. Comparing the observed to predicted frequencies shows how the model slightly underpredicts the frequency of few practices and overestimates the frequency of many practices (compare the numbers in table 3, columns 2 and 3). This occurs because the relatively few growers at either end of the distribution reduce the information available for estimating an accurate model. Nevertheless, figure 2 and table 3 demonstrate that the model fits well to the data.

More importantly, the simulated frequencies show that a population with the minimum level of policy network exposure is predicted to have a much lower incidence of practices. For example, 9% of a population with minimum network exposure is estimated to have six or more practices. In contrast, 50% of the population is expected to have six or more practices when policy network exposure is at the maximum. Any variable that has

---

[7] The predicted policy network distributions are calculated from the ordered probit models by simultaneously holding policy network contacts and watershed activities participation variables at their minimum and maximum levels, respectively, with all other variables at the mean level.

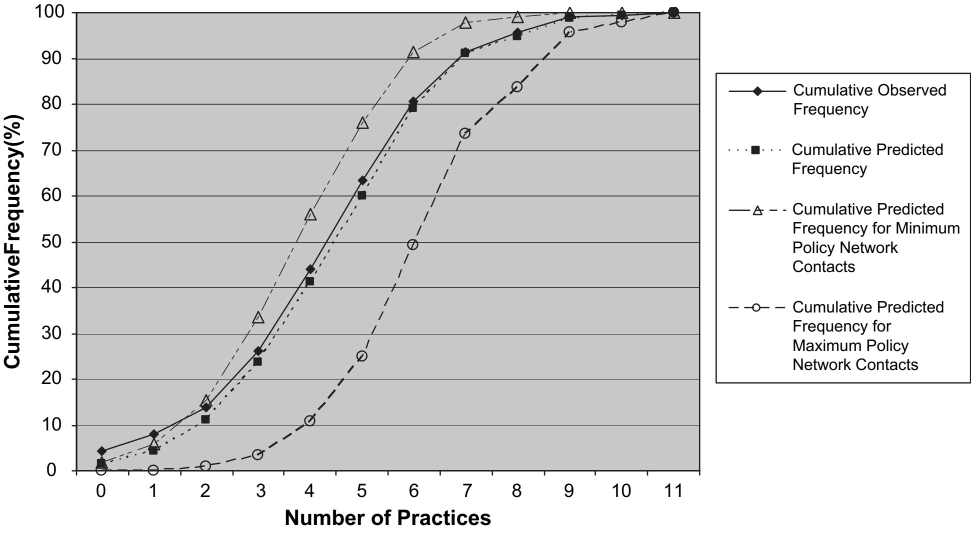
Table 3

Observed Percentages and Average Predicted Probabilities of Number of Practices Adopted

	Overall Practices Scale (Range: 0–11)		Conventional Pest Management Practices (Range: 0–6)		Alternative Pest Management Practices (Range: 0–3)		Runoff Control Practices (Range: 0–2)	
Number of Practices	Observed Percentage	Average Predicted Probability	Observed Percentage	Average Predicted Probability	Observed Percentage	Average Predicted Probability	Observed Percentage	Average Predicted Probability
0	4.41	.014	7.60	.036	54.90	.527	36.27	.328
1	3.68	.028	4.17	.048	33.82	.356	40.44	.427
2	5.88	.066	12.99	.151	8.33	.082	23.28	.245
3	12.25	.127	27.70	.262	2.94	.034	—	—
4	17.65	.176	25.98	.268	—	—	—	—
5	19.61	.187	19.12	.199	—	—	—	—
6	17.16	.190	2.45	.033	—	—	—	—
7	10.78	.119	—	—	—	—	—	—
8	4.17	.038	—	—	—	—	—	—
9	3.43	.038	—	—	—	—	—	—
10	0.49	.007	—	—	—	—	—	—
11	0.49	.006	—	—	—	—	—	—

Note: Observed percentages are the percentage of growers with a particular number of practices as observed in the sample. Average predicted probability is the predicted probability of observing a grower with a particular number of practices, as calculated from the ordered probit models in table 3. The "overall practices scale" is the sum of the three subscales.

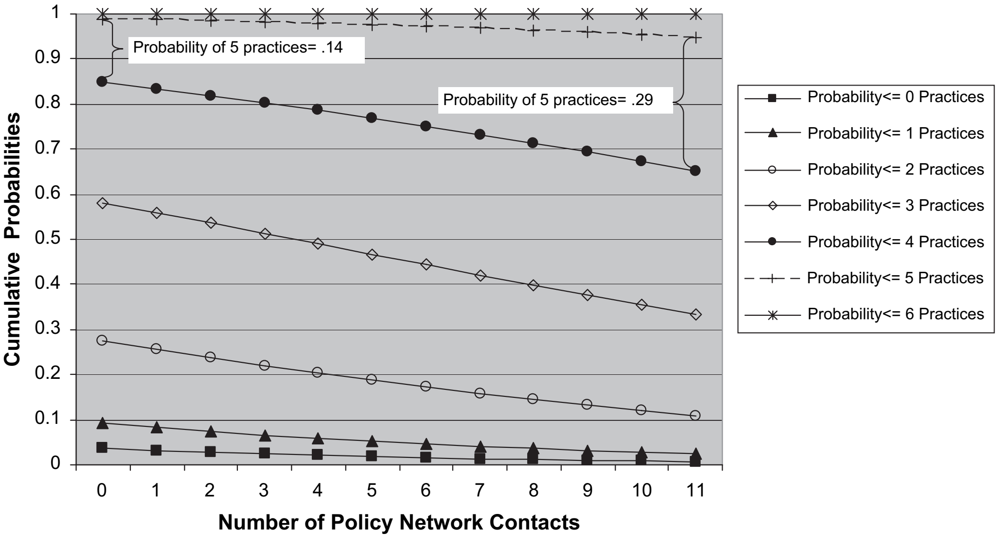
Figure 2
Observed and Predicted Cumulative Frequencies of BMP Adoption



a positive coefficient in the ordered probit models will lead to a similar shift along the adoption probability curve.

The relative importance of each independent variable can be assessed by analyzing how changes in the independent variables affect the predicted probabilities. Figure 3 illustrates by plotting the cumulative probabilities of different numbers of conventional pesticide practices on the vertical axis, moving from the minimum to the maximum of

Figure 3
Cumulative Probabilities of Conventional Pesticide Practices as Function of Policy Network Contacts



number of policy network contacts on the horizontal axis. The spaces between the lines on the figure indicate the probability of having a specific number of practices. For example, when a grower has no network contacts, there is a .14 probability of having five conventional pesticide management practices. As the number of network contacts increases, the probability of five practices increases to .29, for a difference of .15. Note the nonlinear nature of these probability changes, and also that increases in the probability of a high number of practices correspond with decreases in the probability of low numbers of practices.[8]

Table 4 presents two additional quantities of interest from these types of probability distributions as calculated for each model.[9] First, the average absolute probability change moving from the minimum to the maximum of each significant independent variable captures the overall influence of that variable on the entire distribution. For example, moving from the minimum to the maximum of the policy network scale changes the probability of zero runoff practices by $-.18$, the probability of one practice by .01, and the probability of two practices by .17, which equals an average absolute probability change of .12. Second, the discrete change in the probability of being an "innovator" moving from the minimum to the maximum of each significant independent variable. The probability of being an innovator is defined as the sum of probabilities for having more than the median number of practices on each scale.[10]

Table 4 shows that policy networks matter. For the overall practices scale, moving from the minimum to the maximum range of the policy network variable increases the probability of being an innovator by .29, whereas moving across the range of the watershed management activities scale increases the same probability by .26. This compares to an increase of .15 for pesticide awareness, .13 for practices awareness, and .52 for the walnut acres scale. The fact that walnut acres is the variable with the largest single effect reemphasizes the importance of farm structure, in particular how operation size provides economies of scale in adopting BMP and how implementation must reflect the unique factors of each operation. What this means is that farm structure cannot be ignored; the agricultural, environmental, and economic characteristics of an operation determine the opportunities for BMP implementation. Policy networks make possible the realization of those opportunities by increasing awareness of practices, providing a reservoir of social capital, and enabling cultural change.

The results also show some interesting differences in how strongly policy networks influence each category of management practices. Policy networks have the strongest influence on conventional pest management practices, a weaker influence on runoff control practices, and a negligible influence on alternative pest management. One likely explanation for this pattern is the relative age of these innovations—whereas conventional pest management techniques have been evolving since the late 19th and early 20th centuries, alternative pest management began to appear in the 1960s (Aspelin 2003). The local policy

---

[8] The downward slopes of the lines in figure 3 can be confusing and do not indicate decreasing probabilities. Because the figure is graphing cumulative probabilities, what is important is the vertical space between the lines as indicated by the labels in the figure.

[9] These quantities are examined separately for each significant independent variable, holding the other independent variables at their mean levels.

[10] For example, in figure 3 the probability of a grower with zero policy network contacts being an innovator is equal to the sum of the probability of having four, five, and six practices. These probabilities change over the range of the network contacts variable.

Table 4
Average Absolute Probability Changes and Discrete Changes in Probability of Being an Innovator

	Overall Practices Scale	Conventional Pest Management Practices	Alternative Pest Management Practices	Runoff Control Practices
Farm operation characteristics				
Almond acres	NS	NS	NS	NS
Peach acres	NS	NS	NS	NS
Prune acres	NS	NS	NS	Avg. |Prob Δ| = .37 ΔP (innovator) = .56
Walnut acres	Avg. |Prob Δ| = .09 ΔP (innovator) = .52	Avg. |Prob Δ| = .10 ΔP (innovator) = .35	Avg. |Prob Δ| = .21 ΔP (innovator) = .41	NS
Number of orchard types	Avg. |Prob Δ| = .05 ΔP (innovator) = .30	Avg. |Prob Δ| = .08 ΔP (innovator) = .29	NS	NS
Gross farm income	NS	NS	NS	NS
Awareness				
Pesticide awareness	Avg. |Prob Δ| = .02 ΔP (innovator) = .15	Avg. |Prob Δ| = .03 ΔP (innovator) = .10	Avg. |Prob Δ| = .06 ΔP (innovator) = .12	Avg. |Prob Δ| = .05 ΔP (innovator) = .07
Practices awareness	Avg. |Prob Δ| = .02 ΔP (innovator) = .13	Avg. |Prob Δ| = .06 ΔP (innovator) = .19	NS	NS
Farm operator characteristics				
Environmental values	NS	Avg. |Prob Δ| = .05 ΔP (innovator) = .19	NS	NS
Years in agriculture	NS	NS	NS	NS
Education	NS	NS	NS	NS
Network exposure				
Number of watershed management activities	Avg. |Prob Δ| = .04 ΔP (innovator) = .25	Avg. |Prob Δ| = .06 ΔP (innovator) = .21	NS	Avg. |Prob Δ| = .09 ΔP (innovator) = .12
Number of policy network contacts	Avg. |Prob Δ| = .05 ΔP (innovator) = .29	Avg. |Prob Δ| = .07 ΔP (innovator) = .25	NS	Avg. |Prob Δ| = .12 ΔP (innovator) = .17

Note: Table entries are average absolute probability change (Δ) for all numbers of practices, and discrete change (Δ) in probability of being an "innovator", moving across the entire range of the significant independent variables for each ordered probit model. Innovators are defined as growers with more than the median number of practices for each scale. For BMP scale, innovators have six or more practices. For conventional pest management scale, innovators have four or more practices. For alternative pest management scale, innovators have one or more practices. For runoff control scale, innovators have two practices. NS = not significant.

network thus provides greater exposure to conventional pest management practices, many of which are used for purely economic purposes (e.g., saving pesticide costs) but are now also being promoted for water quality management. Techniques like alternative pest management practices are younger and not as widely discussed, and therefore the influence of networks is weaker. The fact that pesticide awareness has a stronger influence on alternative pest management than conventional pest management suggests that perceptions of environmental problems are an important motivator for the newer innovations. However, as the technology and knowledge about alternative pest management practices continues to develop, it is likely that policy networks will have an increasing influence on producer behavior. This suggests that especially for brand new management practices, policy makers should pay attention to achieving high levels of awareness among members of the policy network.

Testing for Reciprocal Causality: Two-Stage Least Squares

One potential challenge to the conclusion of the above analysis is that growers who intend to implement BMP will construct local networks to facilitate adoption. If this is true, then there is potentially a reciprocal causal relationship between BMP adoption and network exposure. To test this possibility, table 5 reports two-stage least squares models using the overall BMP scale, where both the number of watershed management activities and policy network contacts are considered endogenous variables that could be influenced by BMP frequency. To identify the system of equations, the equations predicting BMP frequency use only the significant variables from the earlier analysis, and the insignificant farm structure variables are used in the network exposure equations. The linear structure of two-stage least squares does not provide the advantages of ordered probit, but there is enough range on the overall practices scale to maintain the linearity assumption at least for detecting reciprocal causality.

The results in table 5 show no evidence of reciprocal causality: the overall BMP scale is not a significant predictor of either measure of network exposure. Both measures of network exposure remain significant with substantively important magnitudes. The analysis also demonstrates that more wealthy operations and better-educated growers have higher levels of network exposure. Thus these variables will have some indirect influence on BMP adoption by increasing network exposure. This speaks to the cultural change role of policy networks, where attitudes and behaviors spread via social learning from agricultural leaders to more disconnected and potentially less innovative segments of the agricultural community. Lubell (2005) calls this nexus between policy network contacts and agricultural leaders the “vanguard of cooperation.”

Whereas the analysis suggests a one-way flow of causality from policy networks to BMP adoption, two-stage least squares requires some strong assumptions about what variables are excluded from each equation to identify the system. But even if the statistical tests are completely wrong, and in fact there is reciprocal causality, the importance of policy networks still stands. Imagine a grower who decides she wants to implement BMP on her farm and is looking for help in doing so. The grower will first look to local contacts; she will not think about going to the state capital where the policies originate. If those local contacts do not exist, then either the behavior may not occur or the grower will have to incur higher costs to assemble a network. Regardless of the direction of causality, there is a tight link between the frequency of BMP adoption and exposure to local policy networks.

Table 5
Two-Stage Least Squares Models for Reciprocal Relationship between BMP Scale and Network Exposure Variables

	Number of Watershed Management Activities	Number of Policy Network Contacts
Two-stage least squares equations predicting BMP scale		
Independent variables		
Walnut acres (100 s)	.154 (.063)**	.176 (.058)**
Number of orchard types	.267 (.123)**	.159 (.131)
Pesticide awareness	.645 (.261)**	.492 (.278)*
Practices awareness	.271 (.372)	.613 (.294)**
Number of watershed management activities	.886 (.348)**	—
Number of policy network contacts	—	.360 (.129)**
Constant	2.624 (.321)**	2.50 (.331)**
Model fit	$F = 17.96^{**}, R^2 = .151$	$F = 19.02^{**}, R^2 = .19$
Two-stage least squares equations predicting network exposure variables		
Independent variables		
BMP scale	.139 (.180)	.180 (.370)
Pesticide awareness	.125 (.204)	.755 (.419)*
Practices awareness	.459 (.231)**	.294 (.474)
Gross farm income	.074 (.046)*	.327 (.094)**
Years in agriculture	.003 (.005)	.008 (.010)
Education	.111 (.042)**	.143 (.086)*
Constant	−.590 (.564)	.120 (1.15)
Model fit	$F = 10.50^{**}, R^2 = .192$	$F = 14.55^{**}, R^2 = .232$

Note: Table entries are unstandardized parameter estimates from two-stage least square models where the top equations have the BMP scale as the dependent variable and the bottom equations have each measure of network exposure as the dependent variable. Two-tailed t-tests of null hypothesis that parameter = 0: $^{**}p < .05$; $^{*}p < .10$, $N = 331$ for all models.

Further research using panel data will be needed to provide better evidence about the dynamics of the relationship. For now, the following quote from a personal interview of a Sacramento Valley grower serves to illustrate the quantitative results:

> I have great confidence in the abilities of the Glenn County Ag Commissioner's office because I see what they do. They're out there proving every day their competence and they're free to admit if they don't know, or if something is beyond their expertise they'll admit that. But I don't have that day-to-day contact with the Regional Board, it's more a longer time period between the contact. And they haven't come out and said we don't know. In my family, we're firm believers that if you don't know, say so. Don't try to b.s. your way through something, to try and cover up.

CONCLUSION

The analysis presented here reflects the traditional debate between normative "top-down" and "bottom-up" perspectives on policy implementation (Matland 1995). Top-down models often reflect the naive, legalistic viewpoint that assumes legislation leads to agency decisions, which in turn cause immediate, widespread, and error-free behavioral change in some target group. Bottom-up models (e.g., Hjern and Hull 1982) argue that one cannot ignore the political and social processes underlying policy implementation, where policy outcomes are an emergent property of collective decisions by many individual actors including a range of local public agencies. The top-down view can often lead to frustration on the part of policy advocates, who wish to see their preferred policies implemented as quickly as possible but instead see substantial deviance between policy goals and outcomes.

Although undoubtedly any realistic model of policy implementation requires blending top-down and bottom-up perspectives, this article shows that local policy networks are an integral part of the implementation process in the context of agricultural watershed management. Local policy networks spread information about behaviors and policies, provide reservoirs of social capital, and enable cultural change. Our study demonstrates quantitatively that agricultural producers' exposure to policy networks increases the probability of adopting environmental BMP. Without the active cooperation of local policy networks, policies such as the Waiver and associated SVWQC would surely languish and fail. This is especially true in the case of collaborative policies that rely on some element of voluntary compliance. Even in the case where regulators have strong punishments available for non-compliance, supportive policy networks will reduce the costs of monitoring and enforcement.

The key lesson from the public administration perspective is that the decisions of public managers at the state and Federal level can directly affect the strength of local policy networks. Public managers may reduce investments in local networks in the face of budget cuts or perhaps in reaction to political changes that shift government resources from one sector to another. These changes in local networks will have direct effects on the effective implementation of policies like agricultural watershed management, which depends on interactions between agency officials, non-profit organizations, and farmers. The irony is that at the same time agriculture is being asked to increase awareness of environmental issues, the very policy networks necessary to create such change are being dismantled. This dismantling of local networks is especially problematic if, as some scholars argue, social capital is difficult to create and easy to destroy.

Agricultural watershed management is certainly not the only policy area in which local networks should matter. Urban watershed management is designed to solve the similar collective action problems of urban nonpoint source pollution and water conservation. Urban programs also tend to use collaborative strategies to encourage change in household practices. Residents that are embedded in local policy networks are more likely to participate in these types of policies. Further studies are needed to identify the agencies and organizations involved with these urban policy networks and how they connect to citizens.

Local networks are probably also necessary for the success of collaborative environmental policy in general. Large-scale ecosystem management programs like the Chesapeake Bay Program, Comprehensive Everglades Restoration Plan, and CALFED Bay-Delta develop restoration plans that are implemented through joint action from multiple local agencies and individuals. These same programs also try to solve collective action problems involving individual behaviors such as urban/agricultural nonpoint source pollution. The question of scale will be important in this context, because the formation and function of networks in large-scale programs may be different than for smaller scale programs that focus on individual watersheds, with few layers of bureaucracy between decision makers and resource users.

Finally, at the most general level is implementation of any type of policy that attempts to solve collective action problems through widespread behavioral change at the individual level. Environmental policy is only one place in which collective action problems are at the heart of implementation. For example, educational policies that attempt to build civic involvement will also need to think hard about the structure and function of local policy networks linking parents and youth to the policy programs. Discussing every other policy domain in which collective problems occur is beyond the scope of this article. But in these types of settings, local policy networks will be crucial to the social process of implementation.

FUNDING

The Russell Sage Foundation Initiative on Trust (82-02-05) and the California Policy Research Center (EEN06A).

REFERENCES

Aspelin, A. L. 2003. *Pesticide usage in the United States: Trends during the 20th century. Chapter 2. Background on history of pesticide use and regulation in the U.S.* Raleigh, NC: Center for Integrated Pest Management, North Carolina State University, Technical Bulletin 105.

Axelrod, Robert. 1984. *The evolution of cooperation.* New York, NY: Basic Books.

Berry, Frances Stokes, and William D. Berry. 1990. State lottery adoptions as policy innovations: An event history analysis. *American Political Science Review* 84:395–415.

———. 1992. Tax innovation in the states—Capitalizing on political opportunity. *American Journal of Political Science* 36:715–42.

Bosch, Darrell J., Zena L. Cook, and Keith O. Fuglie. 1995. Voluntary versus mandatory agricultural policies to protect water quality: Adoption of nitrogen testing in Nebraska. *Review of Agricultural Economics* 17:13–24.

Burt, Ronald S. 1992. *Structural holes: The social structure of competition.* Cambridge, MA: Harvard Univ. Press.

Chiffoleau, Y. 2005. Learning about innovation through networks: The development of environment-friendly viticulture. *Technovation* 25:1193–204.

Coleman, James S. 1990. *Foundations of social theory.* Cambridge, MA: Harvard Univ. Press.

Conley, T., and C. Udry. 2001. Social learning through networks: The adoption of new agricultural technologies in Ghana. *American Journal of Agricultural Economics* 83:668–73.

Dillman, Don A. 2000. *Mail and internet surveys: The tailored design method.* New York, NY: John Wiley and Sons.

Feather, P. M., and G. S. Amacher. 1994. Role of information in the adoption of best management-practices for water-quality improvement. *Agricultural Economics* 11 (2–3): 159–70.

Foster, A. D., and M. R. Rosenzweig. 1995. Learning by doing and learning from others—Human-capital and technical change in agriculture. *Journal of Political Economy* 103:1176–209.

Fuglie, Keith O., and Catherine A. Kascak. 2001. Adoption of diffusion of natural-resource-conserving agricultural technology. *Review of Agricultural Economics* 23:386–403.

Fulton, Allan, B. Krueger, and C. Little. 2001. Evaluation of resident vegetation and cover crops on infiltration and runoff characteristics of an orchard soil. CALFED Annual Report: 8.

Grant, Joe, Carolyn Pickel, Robert Van Steenwyk, and Stephen Welter. 2004. Management of codling moth using sprayable microencapsulated pheromones with selective insecticides. *Walnut Research Reports*: 195–206.

Greene, William H. 2000. *Econometric analysis.* Upper Saddle River, NJ: Prentice-Hall.

Henrich, Joseph. 2001. Cultural transmission and the diffusion of innovations: Adoption dynamics indicate that biased culture transmission is the predominate force in behavioral change. *American Anthropologist* 103:992–1013.

Hjern, Benny, and Chris Hull. 1982. Implementation research as empirical constitutionalism. *European Journal of Political Research* 10:105–15.

Karp, David Gutierrez. 1996. Values and their effect on pro-environmental behavior. *Environment and Behavior* 28:111–33.

Long, J. Scott. 1997. *Regression models for categorical and limited dependent variables.* Thousand Oaks, CA: Sage Publications.

Lubell, Mark. 2005. Public learning and grassroots cooperation. In *Adaptive governance and water conflict*, ed. John T. Scholz and Bruce Stiftel, 174–184. Washington, DC: Resources for the Future.

Lubell, Mark, Mark Schneider, John T. Scholz, and Mihriye Mete. 2002. Watershed partnerships and the emergence of collective action institutions. *American Journal of Political Science* 46:148.

Marshall, Graham. 2005. *Economics for collaborative environmental management: Renegotiating the commons.* London: Earthscan Publications Ltd.

Matland, Richard E. 1995. Synthesizing the implementation literature: The ambiguity-conflict model of policy implementation. *Journal of Public Administration Research and Theory* 5:145.

Mintrom, M., and S. Vergari. 1998. Policy networks and innovation diffusion: The case of state education reforms. *Journal of Politics* 60:126–48.

Napier, T. L., C. S. Thraen, A. Gore, and W. R. Goe. 1984. Factors affecting adoption of conventional and conservation tillage practices in Ohio. *Journal of Soil and Water Conservation* 39 (3): 205–9.

Napier, T. L., C. S. Thraen, and S. L. McClaskie. 1988. Adoption of soil conservation practices by farmers in erosion-prone areas of Ohio—The application of logit modeling. *Society and Natural Resources* 1:109–29.

Napier, T. L., and M. Tucker. 2001. Use of soil and water protection practices among farmers in three midwest watersheds. *Environmental Management* 27:269–79.

Napier, T. L., M. Tucker, and S. McCarter. 2000. Adoption of conservation production systems in three midwest watersheds. *Journal of Soil and Water Conservation* 55 (2): 123.

Napier, T. L., and S. M. Camboni. 1988. Attitudes toward a proposed soil conservation program. *Journal of Soil and Water Conservation* 43 (2): 186–91.

Napier, T. L., S. M. Camboni, and C. S. Thraen. 1986. Environmental concern and the adoption of farm technologies. *Journal of Soil and Water Conservation* 41 (2): 109–13.

Ostrom, E. 1994. Constituting social capital and collective action. *Journal of Theoretical Politics* 6:527–62.

Pickel, C., J. Grant, and S. Welter. 2005. Using aerosol pheromone "Puffers" for area-wide suppression and sprayable pheromone in management of codling moth in walnuts. *Walnut Research Reports*: 177–93.

Putnam, Robert D. 2000. *Bowling alone: The collapse and revival of American community.* New York, NY: Simon and Schuster.

Richerson, Peter J., and Robert Boyd. 2005. *Not by genes alone: How culture transformed human evolution.* Chicago, IL: Univ. of Chicago Press.

Rogers, Everett. 2003. *Diffusion of innovations.* New York, NY: Free Press.

Sabatier, Paul A., Will Focht, Mark Lubell, Zev Trachtenburg, Arnold Vedlitz, and Marty Matlock, eds. 2005. *Swimming upstream: Collaborative approaches to watershed management.* Cambridge, MA: MIT Press.

Schneider, M., J. Scholz, M. Lubell, D. Mindruta, and M. Edwardsen. 2003. Building consensual institutions: Networks and the national estuary program. *American Journal of Political Science* 47:143–58.

Scott, John. 2000. *Social network analysis: A handbook.* Thousand Oaks, CA: Sage Univ. Press.

Stern, Paul C., Linda Kalof, Thomas Dietz, and Gregory A. Guagnano. 1995. Values, beliefs, and proenvironmental action: Attitude formation toward emergent attitude objects. Journal of Applied Social Psychology 25:1611–36.

Stern, Paul C., Thomas Dietz, Troy Abel, Gregory Guagnano, and Linda Kalof. 1999. A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecology Review* 6:81–97.

Valente, T. W. 1996. Social network thresholds in the diffusion of innovations. *Social Networks* 18: 69–89.

Valentin, L., D. J. Bernardo, and T. L. Kastens. 2004. Testing the empirical relationship between best management practice adoption and farm profitability. *Review of Agricultural Economics* 26: 489–504.

Wasserman, Stanley, and Katherine Faust. 1994. *Social network analysis: Methods and applications.* New York, NY: Cambridge Univ. Press.

Watts, Duncan. 1999. *The dynamics of networks between order and randomness.* Princeton, NJ: Princeton Univ. Press.

Zalom, F. G., W. Oliver, W. W. Wallender, et al. 2002. Monitoring and mitigating offsite movement of dormant spray pesticides from California orchards. *Acta Hortic* 592:729–35.