7-1-2018

Sustainability Partnerships and Viticulture Management in California

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Publication Information

Hillis, Vicken; Lubell, Mark; and Hoffman, Matthew. (2018). "Sustainability Partnership and Viticulture Management in California". *Journal of Environmental Management, 217,* 214-225. http://dx.doi.org/10.1016/j.jenvman.2018.03.033

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Abstract

Agricultural regions in the United States are experimenting with sustainability partnerships that, among other goals, seek to improve growers' ability to manage their vineyards sustainably. In this paper, we analyze the association between winegrape grower participation in sustainability partnership activities and practice adoption in three winegrowing regions of California. Using data gathered from a survey of 822 winegrape growers, we find a positive association between participation and adoption of sustainable practices, which holds most strongly for practices in which the perceived private benefits outweigh the costs, and for growers with relatively dense social networks. We highlight the mechanisms by which partnerships may catalyze sustainable farm management, and discuss the implications of these findings for improving sustainability partnerships. Taken together, we provide one of the most comprehensive quantitative analyses to date regarding the effectiveness of agricultural sustainability partnerships for improving farm management.

Keywords: Sustainability, farm management, California, viticulture, collaborative governance, social network

Highlights

- Sustainability partnerships promote collaborative governance in agriculture.
- Growers who participate in partnerships manage winegrapes more sustainably.
- Growers with strong social networks manage winegrapes more sustainably.
- Partnerships have the most impact when practices involve perceived benefits.
- Practices that involve perceived cooperative dilemmas pose a greater challenge.

1. Introduction

With over half of US land in agricultural production (Nickerson et al. 2007), agricultural sustainability has become an agenda-setting concept in agricultural policy and environmental management. One emerging means of addressing agricultural sustainability is through the use of sustainability partnerships, defined by Warner (2007a, p.67) as multi-year relationships between at least growers, an agricultural support organization, and scientists to extend knowledge about agricultural and environmental management through applied research and outreach. This article focuses on a primary objective of sustainability partnerships: whether grower participation in partnership activities catalyzes the adoption of sustainable practices that are expected to contribute to economic, social, and environmental goals. Describing and evaluating sustainability partnerships is critical because they are becoming an increasingly important policy tool in agriculture. Our comparative study draws on survey data from over 800 growers in three of the most important wine regions in California, making it one of the most comprehensive analyses to date of these types of partnerships.

Our analysis makes several contributions to research in agricultural and environmental management. First, identifying drivers of sustainability is vital given the enormous impact that agricultural decisions have on food systems and to natural resources on and off the farm. For example, non-point source pollution from agriculture is one of the most severe water quality problems in the US (Davies and Mazurek 2014; Hoornbeek et al. 2013), groundwater over-pumping for irrigation is one of the most severe water supply and quantity issues (Glennon 2012; Wada et al. 2012), and agricultural practices can be detrimental to both worker safety and human health (Damalas and Eleftherohorinos 2011; Horrigan et al. 2002). Sustainability partnerships claim to mitigate the environmental impacts of agriculture, along with providing economic and social benefits that help enhance the overall reputation of particular regions or crops. As with sustainability generally, these specific claims about partnerships are disputed and thus create a demand for evidence-based research.

Second, there is a long-established research tradition in environmental management that examines the diffusion of innovations in agricultural practices (Marra et al. 2003; Pannell et al. 2006; Rogers 2010). This tradition has emphasized the idea of best management practices (BMPs), which promised a synergy between economic and environmental benefits (Baumgart-Getz et al. 2012). Encouraging the adoption of BMPs is the primary goal of many agricultural incentive programs such as the Environmental Quality Incentive Program of the USDA, the European Commission's Joint Research Centre and the European Index for Sustainable Productive Agriculture of the European Conservation Agriculture Federation. Building on the theme of BMPs, sustainable practices seek to integrate social, economic, and environmental goals and often invoke more recent concepts like resilience or adaptive management to environmental change (Lin 2011). Sustainability partnerships also seek to encourage the diffusion of innovations in the form of sustainable management practices, for example, by supporting social networks that spread information about the costs and benefits of innovations and foster norms of cooperation (Warner 2007a).

Third, sustainability partnerships represent the application of the broader idea of collaborative governance to the agricultural sector and sustainability. In the last two decades, collaborative governance has been a central topic of research in public administration and the policy sciences (Ansell and Gash 2008; Biddle and Koontz 2014; Emerson et al. 2012; Lubell et al. 2002; Sabatier et al. 2005; Wyborn and Bixler 2013). Sustainability partnerships represent one of many "species" in the broader "genus" of collaborative governance (Ansell and Gash

2008). Here, we follow the more encompassing definition of collaborative governance used by Emerson et al. (2012), that includes the "processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out a public purpose that could not otherwise be accomplished." This definition encompasses sustainability partnerships, which build formal and informal policy networks among multiple stakeholders including local special districts, Cooperative Extension, pest control advisers, producer associations, university scientists, and regulatory and other governmental officials. Our study thus provides an in-depth examination of a particular instantiation of collaborative governance, which links collaborative governance research to the literature on environmental management in agriculture.

Fourth, instead of narrowly examining the effectiveness of a single policy instrument such as environmental certification (Delmas and Lessem 2017; Potoski and Prakash 2005, 2009), we analyze the relationship between sustainable practice adoption and the full portfolio of activities offered by sustainability partnerships. While all of the partnerships offer third-party sustainability certification programs, the organizations involved also provide a variety of outreach and extension activities that deliver information and assistance regarding government regulation and incentive programs, how to implement agricultural practices, and changes in economic conditions. These partnership activities can catalyze innovation, learning and cooperation in social networks that influence practice adoption (Levy and Lubell 2017; Lubell et al. 2011; Prokopy et al. 2008; Rogers 2010).

Fifth, we examine the effect of partnership participation controlling for two other drivers of grower behavior, the perceived costs and benefits of individual practices and the extent to which growers are embedded within social networks used to share knowledge. The costs and benefits of different practices are customary variables in the diffusion of innovation literature (Rogers 2010), and partnerships also may support the growth and maintenance of social networks. At minimum, it is important to control for these other variables in order to better estimate the correlation between partnership participation and practice adoption. While we do not directly measure economic costs and benefits of the practices, we argue that the perceived costs and benefits that we do measure are important proximate drivers of decision making. Our analysis finds an interaction effect between the perceived benefit/cost ratio of individual practices and partnership participation, and also an interaction effect between the perceived benefit/cost ratio and a grower's centrality in social networks, which suggest that the perceived economics of agricultural decision-making place an important constraint on partnership effectiveness. While other researchers have examined the importance of practice costs and benefits (Pannell, 2008) and the role of social networks in agricultural sustainability (Levy and Lubell 2017; Lubell and Fulton 2007, 2008; Saltiel et al. 1994; Warner 2007a), to our knowledge no analysis has simultaneously considered all of these factors and the interactions among them.

Lastly, since regional variability plays an important role in agriculture generally (Singh and Dhillon 1984), and particularly in viticulture (Peters 1997), our comparative study tests whether our findings are valid in different regional contexts. Previous research on agricultural partnerships has either focused on the performance of single partnerships (Klonsky et al., 1998; Ohmart, 2008; Shaw et al., 2011) or only considered the adoption behaviors of growers participating in more intense research and outreach activities such as self-assessment and certification (CSWA 2009; CSWA 2012). Other studies have relied primarily on qualitative methods or descriptive statistics (Broome and Warner 2008; Prence 1998; Prence and Grieshop

2001; Warner 2007a; Warner 2008). By analyzing data from three of the most important winegrowing regions in California, the findings of our research are more broadly generalizable.

1.1 Sustainability partnerships in California viticulture

The California viticulture industry has embraced the concept of sustainability and the partnership model is well-established as an institutional arrangement for putting sustainability into action (Broome and Warner 2008; Klonsky et al. 1998; Ohmart 2008a; Ohmart 2008b; Ohmart 2011; Prence 1998; Prence and Grieshop 2001; Ross and Golino 2008; Thrupp 1996; Warner 2007a). Beginning in the 1990s, partnerships emerged in most of the state's major viticulture regions and currently operate at both the regional and state scale (Broome and Warner 2008; Warner 2007a). In a previous study of California winegrapes, Warner noted, "California's winegrape growers have undertaken more partnerships to greater effect than those of any other US crop…" (Warner 2007b: 143). Sustainable viticulture partnerships have also developed in other winegrowing regions in the world such as New Zealand (Gabzdylova et al. 2009), South Africa (Von Hase et al. 2010), and Australia (Pomarici et al. 2014), and are beginning to appear in other types of cropping systems such as almonds (Brodt et al. 2006). Hence, viticulture represents an important early example with lessons for agriculture more broadly and also a potential for comparative research.

We focus on sustainability partnerships in three of California's primary winegrowing regions (Elliott-Fisk 2012): Central Coast, Lodi, and Napa Valley. At the time of writing, respectively the primary organizations in each region are the Central Coast Vineyard Team (CCVT), a voluntary membership organization including growers, winemakers and industry partners, with a membership representing over 80,000 acres, the Lodi Winegrape Commission (LWC), a mandatory membership commodity organization representing an estimated 750 growers and 100,000 acres, and the Napa Valley Grape Growers Association (NVGA), a voluntary membership grower and vineyard organization representing approximately 700 growers, vineyard owners and industry partners, including the majority of planted vineyard land in Napa County, California. These lead organizations coordinate networks of regional and statewide grower and vintner organizations, commodity boards, regulators, researchers, individual growers, and consumers (Broome and Warner 2008). All of the partnerships have experienced an evolution from providing technical assistance to growers to promoting BMPs in various ways, whether through promotion of integrated pest management, development of voluntary self-assessment workbooks on sustainability, or more formal third-party sustainability certifications.

1.2 Sustainability partnerships as a species of collaborative governance

It is important to extend the analysis of sustainability partnerships beyond the established idea of diffusion of innovations because they feature a broader set of goals related to innovation, cooperation, and cultural change (Hoffman et al., 2015). The concept of collaborative governance encompasses all of these goals, and sustainability partnerships incorporate the three core principles of collaborative governance identified by Emerson et al. (2012): principled engagement, shared motivation, and capacity for joint action. These principles apply to the interaction among different organizations that sponsor partnership activities, as well as to the individual growers who participate in partnership activities. Here we summarize how sustainability partnerships relate to these three overarching ideas behind collaborative governance, as a way of identifying mechanisms by which partnerships might influence agricultural environmental management.

Principled engagement refers to an inclusive set of stakeholders who interact to discover joint interests and make decisions that achieve mutually beneficial goals. In sustainability partnerships, principled engagement occurs between different private and public organizations, as well as on the part of growers who participate in program development or extension activities (Warner 2008). Leading growers are often represented directly on the advisory boards or other positions of the involved organizations. This collection of actors deliberates about issues such as the definition of sustainability, what types of programs and institutions are necessary to encourage the adoption of sustainable practices among the broader grower community, and communicates the regional reputation to consumers and other actors in the agricultural supply chain. For example, all of the partnerships utilize sustainability self-assessment programs that are the product of mutual collaborative efforts.

Through this process of principled engagement, the participants develop trust and a shared understanding about the goals of the partnership. As with any other collaborative process, developing trust requires many years and sustainability partnerships have evolved from producer groups participating in existing agricultural programs provided by USDA and other agencies, to include broader networks of actors and development of a more unique regional identity. One of the most important aspects of mutual understanding is defining a locally acceptable definition of sustainability and the practices that support it, since not all growers in a given region support the idea and there is some political risk in developing the partnerships.

Lastly, sustainability partnerships develop the capacity for joint action, which focuses on catalyzing processes of learning and cooperation that influence grower decision-making (Lubell et al. 2011). The partnerships offer a range of outreach and education materials and activities such as workbooks, field meetings, on-farm research, internet resources, and conferences. They also actively communicate with supply chain and other stakeholders outside the region in order to build regional reputations. These activities are driven by policy entrepreneurs who promote the idea of sustainability within involved organizations, and also by leading growers who help develop the programs and communicate with other growers. These involved stakeholders help develop the necessary knowledge to define what practices are expected to promote the goals of sustainability, and also seek funding resources such as grants for specific organizations or to help growers participate in USDA and other incentive programs.

1.3 Hypotheses about sustainability partnership effectiveness

In this section, we first identify our primary research hypothesis about the relationship between partnership participation and practice adoption. We then specify hypotheses about the relationship between practice adoption and other variables that are expected to constrain farmer behavior, as well as interactions among them. Sustainability partnerships seek to promote grower adoption of farm practices that balance environmental, economic, and social goals (Pence and Grieshop 2001). Partnerships do not rely on a single policy tool like environmental certification, but rather seek to influence grower behavior using a portfolio of information resources and voluntary incentives. Growers access these policy resources via partnership participation. We offer the following hypothesis about the relationship between partnership participation and adoption of sustainable practices:

> *H1: Winegrape growers who participate in more of the activities offered by sustainability partnerships will also have higher rates of adoption of sustainable practices.*

While observing such a positive association is a necessary but not sufficient indicator of partnership effectiveness, this claim has two important caveats that can only be resolved by additional research. First, while we rely on lists of sustainable practices developed by agricultural experts that are included in the actual sustainability certification programs, there is no guarantee that widespread adoption of these practices will actually improve economic, environmental, and social outcomes. Given the difficulty of measuring these types of outcomes, the partnerships themselves measure grower participation, acreage covered, and practice adoption as indicators of effectiveness. Future research is needed to relate adoption of sustainable management practices to real-world environmental outcomes. Second, our cross-sectional research cannot untangle any reciprocal relationship between participation and practice adoption. Hence, we are making no strong causal claim about directionality, and expect that longitudinal research would uncover a reciprocal and co-evolving relationship between program participation and practice adoption.

A major advantage of our analysis is that we include other important variables that might influence practice adoption and interact with partnership participation. Not only does this allow us to better isolate the effect of partnership participation, it also provides an opportunity to analyze other important theoretical ideas. The large interdisciplinary literature on agricultural decision making has demonstrated that social networks play a key role in practice adoption (Conley and Udry 2010; Hinrichs et al. 2004; Knapp and Fernandez-Gimenez 2009; Korsching and Malia 1991; Lubell and Fulton 2008, 2007; Norman and Huerta 2006; Prokopy et al. 2008). Social networks facilitate the development of trust and reputation, which are crucial forms of social capital for solving the cooperation problems inherent to sustainability issues (Ostrom 1994; Pretty 2003; Shrestha 2013). Social networks provide a pathway for social learning from others about practices, and participation in sustainability partnerships may facilitate the development of relationships. We thus offer the following hypothesis about the role of social networks:

H2: Winegrape growers with more information-sharing network ties will adopt more sustainable practices.

Agricultural operations are fundamentally economic enterprises that react to the economic benefits and costs of different practices. We improve over previous research by measuring the perceived economic benefits and costs of 44 different sustainable practices that are commonly included in the self-assessment workbooks and certification programs. We also measure the perceived environmental benefits of the same set of practices. While we do not measure costs and benefits directly, we argue that the perceived, relative costs and benefits of decision making are important proximate drivers of decision making. For simplicity, throughout the paper we refer to these variables simply as "costs and benefits". We offer the following hypothesis regarding practice benefits and costs:

H3a: Winegrape growers are more likely to adopt sustainable practices with higher perceived economic benefits, and less likely to adopt sustainable practices with higher costs.

H3b: Winegrape growers are more likely to adopt sustainable practices with higher perceived environmental benefits, and less likely to adopt sustainable practices with higher costs.

To integrate these hypotheses, we argue there are interaction effects between the costs and benefits of practices and partnership participation and social network ties. We expect partnership participation and social network ties will have a greater effect on grower behavior for practices with higher benefits and lower costs. To the extent this is true, the benefit/cost ratio of a given practice acts as a constraint on partnership effectiveness, and more expensive practices will continue to have low adoption rates even if they have potentially high environmental or social benefits. Assessing these interactions allows us to examine whether partnerships, and the relationships that they promote, are effective in fostering adoption of practices that represent a cooperative dilemma, or merely those practices that are beneficial to the growers adopting them. Thus, the following hypothesis summarizes the role of interaction effects:

H4: As the benefits of sustainable practices increase and costs decrease, partnership participation and social network ties will have a greater influence on practice adoption.

2. Material and methods

The data used in our analyses were informed by semi-structured interviews and collected with two surveys: a mail survey of winegrape growers and an internet survey of winegrape industry outreach professionals. An advisory committee of 25 growers and outreach professionals from all three regions were consulted through all stages of the research process. We also conducted 16 in-person semi-structured interviews with growers and outreach professionals in the three regions.

In 2010 we conducted an online survey of outreach professionals across the entire California winegrape industry that targeted university researchers, Pest Control Advisers, industry sales representatives, University of California Cooperative Extension staff, grower support organization staff, vineyard managers, viticulture consultants and others. We collected 120 responses for an overall response rate of 43%. Complete results from this survey are reported elsewhere (Lubell et al. 2011), and here we use the data to measure the perceptions about the relative costs and benefits of different practices.

In 2011-12 we conducted a mail survey of winegrape growers in three regions of California. The samples of growers surveyed were created from the 2010-2011 winegrape Pesticide Use Reports from the 10 counties making up the Central Coast region (Alameda, Contra Costa, Monterey, San Benito, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, and Ventura), two making up the Lodi region (Sacramento and San Joaquin), and one in the Napa Valley (Napa). These lists were supplemented, and inaccuracies were corrected to the extent possible, using internet searches of publicly available information. Survey delivery followed the Dillman method, beginning with an invitation letter, followed by a first survey, a reminder, a second survey, a second reminder, and a final reminder (Dillman 2007). Non-respondents with complete contact information were subsequently contacted by telephone and email and encouraged to participate. This survey was the primary data collection instrument and provided all but the cost/benefit measures analyzed in this paper. We collected 822 completed surveys and achieved an overall response rate of 39% (53.4% response rate in Lodi, 42.4% in Napa, and 32.5% in the Central Coast). These response rates are very high for a mail survey conducted in a US farming population. However, we cannot entirely rule out the possibility of non-response bias in our sample. We speculate that if there is systematic non-response it will be that our respondents are more likely to engage in program participation. We do not have any reason to believe that this more participatory group of winegrape growers would respond differently to the experience of participation. Hence, we anticipate that our main effect of program participation on program participation would generalize to more reticent winegrape growers."

2.1 Dependent variable

The dependent variable for the analysis was the adoption decision made by each grower for each of the sustainable practices. We asked respondents about their use of 44 different sustainable practices. An initial list of practices was selected from the *Lodi Winegrower's Workbook* (Ohmart and Matthiasson 2000) in an earlier study conducted by the Lodi Winegrape Commission (Dlott and Dlott 2005). The list of practices thus represents the various management practices that growers can engage in if they want to be more sustainable. The initial list was modified so as to be appropriate for all three regions through consultation with the advisory committee and based on findings from the semi-structured interviews. The survey offered three response categories for each practice: "regularly use", "tried and discontinued", and "never used". Since our main interest is to assess the relationship between partnership participation and growers' use of sustainable practices, we combined the "tried and discontinued" (a very infrequent response) and "never used" responses into a single non-adoption category in the final analysis. It is important to emphasize that the unit of analysis is each grower paired with a specific practice, rather than an aggregate scale that combines practices. This allows us to include practice-level measures of perceived costs and benefits as covariates.

2.2 Independent variables

Partnership participation represents the number of partnership activities each respondent participated in during the last five years, from the following list: attended informational field meetings, attended informational classroom-style meetings, read organization newsletters, spoke with organization staff, accessed organization internet resources, completed a sustainable viticulture certification program, completed a sustainable viticulture self-assessment program, and attended regional and state-wide viticulture industry fairs. In Napa and the Central Coast, there is more than one organization offering these activities. Respondents were thus able to indicate participation in any of the given activities with each of the organizations in the region. In order to standardize responses across regions, we measured participation by summing the number of unique outreach activities in which a respondent participated, without double counting for multiple organizations. For example, if a respondent participated in “attended informational field meetings” with three different organizations, their participation count was increased by only one unit. Our participation measure is thus conservative in not giving extra credit to respondents who have many more participation opportunities, and allows for a fair comparison of participation rates across regions. We quantified participation in three other ways, including the total count of activities participated in, the total number of different organizations a respondent engaged with, and the proportion of total possible activities participated in. Given that we did not find qualitative differences in the results using different measures, we report findings using the measure reported in the main text only, for 1) clarity, and 2) because our measure does not penalize respondents in Lodi (where there is only one lead organization) for low participation rates as would a raw total count, and 3) does not penalize respondents in Napa and Central Coast (where there are multiple organizations) for low participation rates as would a raw proportion of activities participated in.

Network centrality represents the total count of communication and knowledge-sharing relationships an individual has with regards to viticulture management. We constructed the social network by asking respondents to list the names of up to eight other growers and eight outreach professionals with whom they communicated and shared knowledge about viticulture management. We calculated total degree centrality as the total number of network relationships a grower has with other individuals, summing all of the growers who nominated them (in-degree) in the survey, as well as all of the individuals they nominated (out-degree) in the survey (Wasserman and Faust 1994:172).

We also measured the *perceived benefits and costs* of each practice. The online survey of outreach professionals asked respondents to evaluate the perceived 1) economic costs, 2) economic benefits, and 3) environmental benefits of all 44 sustainable practices on 7-point Likert scales. The scale ranged from 1 to 7, with 1 representing "very inexpensive" or "no benefit" and 7 representing "very expensive" or "substantial benefit". We used this data to calculate practice-level mean economic benefit/cost ratios as well as practice-level mean environmental benefits. While these perceived mean benefits and costs are not expressed in actual currency, they adequately capture the relative costs and benefits of the different practices. Further, these measures of perceived benefits and costs have been cross-validated with other attitude data from an independently-conducted survey (Lubell et al. 2011). While asymmetric effects of costs and benefits are possible, here we are particularly interested in the impact of the aggregated benefit/cost ratio because it is the net costs to the individual that determine whether the practice represents a cooperative dilemma.

Finally, we also included a number of individual-level control variables that are standard in agricultural practice adoption research (Prokopy et al. 2008): the number of acres managed (integer), age (6 categories), education level (6 categories), generations the respondent's family has been involved in agriculture (6 categories), gross annual income (8 categories), and years of experience in viticulture (integer).

2.3 Statistical modeling and model selection

To examine the relationship between practice adoption, partnership participation, and other predictor variables, we fit a series of generalized linear multilevel models to the data. In our case, because each respondent indicated their adoption of up to 44 different practices, the unit of analysis is the respondent-practice dyad. Hence, our data features clusters of answers from a single respondent (about different practices they adopted) as well as clusters of answers about a single practice (from different respondents). Multilevel models naturally control for the fact that observations from a given individual, or about a given practice, are not independent. Furthermore, multilevel models can produce more precise estimates about each cluster than a traditional, single-level model can, because they pool information across clusters (McElreath 2016). In order to account for potential correlation between intercepts and independent variables, we also alternately estimated our top-fitting models with fixed intercepts for practices. We found no substantial differences between the models with fixed and random intercepts for practices. We thus report the results from the best four fitting models using random intercepts.

Because each adoption decision consisted of a single yes/no response, we modeled our dependent variable using logistic regression. Each logistic regression contained a random intercept for respondents and a random intercept for practices, as well as a different combination of potential independent variables identified above constructed to test our hypotheses of interest. We fit our data to each candidate regression model and compared model fits using a version of the Akaike information criterion (AIC), adjusted for small sample size: AICc (Burnham and Anderson 2002). AICc provides a relative measure of how well data fit models, incorporating a penalty for additional parameters in order to guard against overfitting. Thus, AICc provides a measure of which model is expected to do the best job of predicting the dependent variable for new cases.

We assessed the importance of a particular predictor based on whether or not the variable was included in the best fitting models, as well as the change in AICc in models that either contain or omit the variable in question. Following Burnham and Anderson (2002), we also calculate relative variable importance by summing the relative weight of all models that contain a particular variable. This is an alternative to the standard null hypothesis testing approach that assesses whether or not a coefficient is significantly different from zero at some normative probability level. The relative precision of each estimate is indicated by the standard error, and the consistency of each estimate and standard error across models provides a validity check. We estimated the effect of important predictors by computing predictions based on the top four fitting models. The models are ranked by AICc value, where lower values indicate better fitting models that are expected to make better predictions of future cases. The AICc weights represent the relative likelihood of each model and the top four best fitting models represent all models with greater than 0.1 AICc weight. Thus, using the top-four fitting models combined to plot predictions for all our variables is a conservative approach, as it incorporates model uncertainty. See the Appendix for detailed information about the model selection process. All analyses were performed in R 2.15.3 (R Core Team 2013) and made use of the "lme4" package (Bates et al. 2012) for estimating statistical models, and "statnet" (Handcock et al. 2003) package for calculating network measures.

3 Results

3.1 Variation in practice adoption

Figure 1 reports substantial variation in the percentage of survey respondents who indicated whether they currently use each of the 44 different practices, grouped into seven different categories. Practice categories with high adoption rates, such as disease, pest, and weed management, typically provide growers with more direct and short-term economic benefits and are core aspects of vineyard management. In contrast, the economic benefits of practices with lower adoption rates, such as business management and alternative energy, are more likely to be realized only in the long term.

Table 2 reports the standard deviation of the distribution of the probability of adoption among respondents (in the row labeled "Respondent (sd)") and among practices (in the row labeled "Practices (sd)"). For respondents, this quantity ranges from 0.753 to 0.754, while for practices, this quantity ranges from 1.038 to 1.052, across the models. Thus, there is greater variation in adoption among practices than there is variation in adoption among growers. In other words, unobserved heterogeneity among practices is more influential than heterogeneity among individuals in determining practice adoption. Substantively, even after controlling for perceived benefits and costs, there are some practices that are consistently adopted at higher or lower rates due to unmeasured aspects of those practices that may be linked to attributes of innovations that can influence adoption rates, such as uncertainty about outcomes (Rogers 2010). While the random intercepts of our model adequately capture this unobserved heterogeneity, future research could more explicitly measure important practice-level variables.

3.2 Practice adoption is positively associated with partnership participation

Consistent with H1, partnership participation has a positive coefficient and consistent standard error in all of the top four models. Figure 2 reports the probability of adopting any given single practice as a function of partnership participation, based on model-averaged predictions from the best four fitting models using the AICc weight of each model. Each panel displays the relationship between participation and the probability of adoption of a sustainable practice, for differing levels of costs and benefits, with the costliest practices in the far-left panel, and the least costly practices in the far-right panel. Overall, the probability of adoption is positively associated with partnership participation, but the relationship is strongest for practices that are the least costly (right-most panel; we discuss this interaction in more detail in Section 3.5).

Table 2. Parameter estimates and standard errors for each variable (by row) in the top four fitting models (by column) according to AICc. The dependent variable in each model is the adoption decision made by growers about practices. Predictor variables include the random intercepts for practice and respondent, and fixed effects for variables of interest and demographic controls.

	Model 1		Model 2		Model 3		Model 4	
Variable	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Intercept	-0.091	(0.170)	-0.091	(0.170)	-0.090	(0.168)	-0.091	(0.168)
Participation	0.138	(0.017)	0.138	(0.017)	0.138	(0.017)	0.138	(0.017)
Degree	0.028	(0.009)	0.028	(0.009)	0.028	(0.009)	0.028	(0.009)
Net B/C	1.061	(0.346)	1.063	(0.345)	1.091	(0.343)	1.094	(0.342)
Participation x Net B/C	0.049	(0.016)	0.058	(0.015)	0.050	(0.016)	0.058	(0.015)
Degree x Net B/C	0.014	(0.009)	--	--	0.014	(0.009)	--	--
Public Ben	--	--	--	--	-0.246	0.235	-0.247	(0.235)
Acres	0.240	(0.023)	0.240	(0.023)	0.240	(0.023)	0.240	(0.023)
Age	-0.022	(0.039)	-0.022	(0.039)	-0.022	(0.039)	-0.022	(0.039)
Education	0.059	(0.032)	0.059	(0.032)	0.059	(0.032)	0.059	(0.032)
Experience	-0.008	(0.003)	-0.008	(0.003)	-0.008	(0.003)	-0.008	(0.003)
Generation	0.019	(0.027)	0.019	(0.027)	0.019	(0.027)	0.019	(0.027)
Lodi	-0.591	(0.108)	-0591	(0.108)	-0.591	(0.108)	-0.591	(0.108)
Napa	0.126	(0.091)	0.127	(0.091)	0.127	(0.091)	0.127	(0.091)
Observations	21310		21310		21310		21310	
Practices (#)	44		44		44		44	
Respondents (#)	497		497		497		497	
Practice (sd)	1.052		1.051		1.039		1.038	
Respondent (sd)	0.753		0.754		0.753		0.754	
AICc	22642.9		22643.4		22643.8		22644.3	
AICc Weight	0.34		0.26		0.21		0.17	

3.3 Growers with more social network connections adopt more sustainable practices

Total degree centrality has a positive coefficient and consistent standard error in all of the top four models, which supports H2, that growers with more social network connections are more likely to adopt practices. Figure 3 plots the predicted relationship between total degree and practice adoption, again using the best four fitting models. Each panel displays the relationship between the number of social network connections an individual has and the probability of adoption of a sustainable practice, again for differing levels of costs and benefits, with the costliest practices in the far-left panel, and the least costly practices in the far-right panel. On average, the probability of adoption is positively associated with a grower's number of social network connections but strongest for practices that are least costly (right-most panel; we discuss this interaction in more detail in Section 3.5).

3.4 Sustainable practices perceived to have high economic costs and low economic benefits are less likely to be adopted

As expected by H3, the perceived private benefit-cost ratio is positively associated with practice adoption in all of the best fitting models. Figures 2 and 3 illustrate the positive correlation between practice adoption and economic benefit/cost ratio in the vertical upward movement of the lines across the panels. For example, when partnership participation equals zero (vertical axis intercept in Figure 2) and the benefit/cost ratio is -1.3 (i.e., benefits are less than costs) the probability of practice adoption is approximately 20%, while moving to a benefit/cost ratio of 1.3 raises the probability of practice adoption to nearly 80%. The same pattern is apparent in Figure 3, where increasing the benefit/cost ratio is correlated with higher rates of practice adoption at all levels of network connections.

Perceived environmental benefits, on the other hand, are not an important predictor of practice adoption. Environmental benefits are missing from the top fitting model, and while it is included in the second-best fitting model, adding environmental benefits to a model actually results in about a 1-2 unit worsening in AICc, indicating that models with the environmental benefits variable actually perform worse than do those without. Furthermore, while the standard errors are large relative to the magnitude of the environmental benefits coefficients, the estimates are actually negative suggesting that environmental benefits could even reduce the rate of practice adoption. Regardless of whether the environmental benefits have no important effect or a negative effect on the rate of practice adoption, these results suggest that farm-level practices that produce environmental benefits face substantial collective-action problems.

3.5 Partnership participation and social network relationships are most effective when practice benefit to cost ratios are high

Consistent with H4, we find evidence of interaction effects between the perceived economic benefit/cost ratio and partnership participation and social network connections. This interaction is particularly important in the case of partnership participation, which is included in all four top-fitting models. The interaction between social network connections and benefit/cost ratio is weaker, and included in only two of the top models. Still, the two models that contain this interaction have AICc values roughly 0.5 units less than corresponding models without the interaction. Thus, including the interaction improves the predictive value of the model overall. The relative variable importance of this interaction effect is greater than 0.55 – given its presence in two of the top-fitting models that include almost all of the AICc weight. Models including the interaction between participation and the benefit/cost ratio perform even better – the AICc values drop by roughly 7 units when including this interaction and the relative variable importance approaches 1, because it is contained in all four of the top-fitting models. Thus, while the interaction with degree has some explanatory power, the interaction with participation is far stronger.

These interactions are displayed in Figures 2 and 3 respectively, which illustrate the predicted probability of practice adoption as a function of partnership participation and total degree centrality, for three levels of benefit/cost ratios (costliest, intermediate, and least costly, moving from left to right in the figures). As can be seen from comparing the slopes of the lines in each panel, the positive effect of participation and social network ties is strongest for practices with high relative benefits to costs. Information is the key constraint to the adoption of practices with a positive benefit-cost ratio, because if growers have information about them, on average they directly improve the economic welfare of the farm. The positive effect of participation and social network ties is weakest for practices with high relative costs to benefits. These are practices that can represent a cooperative dilemma (private costs are greater than private benefits), because even if those practices provide environmental benefits individual growers are potentially paying private costs that may only be offset if enough other growers also adopt those practices.

3.6 Other demographic factors

In order to focus primarily on our main hypotheses, we included demographic variables in all models (rather than systematically including and omitting them). The parameter estimates on these variables are largely consistent with previous research. Growers with larger farms are more likely to adopt sustainable practices, and the size of the effect is large and reliable across models.

Geographic region is also associated with grower adoption of sustainable practices. Specifically, growers in Lodi adopt fewer sustainable practices than do growers in Napa and the Central Coast. Predictions from the top four fitting models indicate that a grower from the Central Coast is predicted to adopt with a probability of about 48%, a grower from Lodi is predicted to adopt with a probability of about 34%, and a grower from Napa is predicted to adopt with a probability of 50%.

Finally, growers' years of experience in agriculture has a modest negative influence on practice adoption in all models. Model predictions indicate a grower with relatively little experience will adopt practices with a probability of under 50% while a grower with about 20 years of experience (a little more than the median amount observed in the data) is predicted to adopt practices with a probability below 45%. A grower with 60 years of experience is predicted to adopt practices with a probability approaching 35%.

4. Conclusion

The goal of this paper is to analyze the effectiveness of sustainability partnerships as a species of collaborative governance applied to agriculture, where networks of stakeholders cooperate to provide outreach activities that encourage growers to adopt more sustainable practices.

We found grower participation in partnership activities to be strongly and positively associated with practice adoption in all three regions, controlling for other important drivers of decision making. While our cross-sectional design requires specifying empirical models that imply partnership participation increases practice adoption, it is important to reiterate the adage that correlation does not equal causation. In reality, there is likely a reciprocal and co-evolutionary relationship between practice adoption and partnership participation. Our model results are consistent with this more complex hypothesis, but only longitudinal data or more sophisticated statistical tests making strong assumptions (Shaw, Lubell, and Ohmart 2011) will allow a more complete test. Regardless, observing a positive association is a necessary pre-condition for claiming that partnerships are an effective approach for influencing grower behavior.

Including social network connectivity in our analysis provides insight into the social processes by which growers learn about agricultural management. Social learning among a local network of growers and outreach professionals is considered a primary pathway for accessing and spreading knowledge (Foster and Roszenweig 1985; Roling and Wagemakers 1998; Warner 2007a; Lubell et al. 2014). Our finding that the number of social network relationships is a good predictor of practice adoption supports this argument. We argue that the outreach activities hosted by sustainability partnerships are promoting practice adoption because they provide a forum for growers to build new knowledge-sharing relationships and trust with outreach professionals and other growers. This result is consistent with similar “network smart” extension strategies that work to rewire the local knowledge networks among growers and outreach professionals and have the potential to enhance the benefits of social learning (Hoffman et al., 2015).

This study takes the important empirical step of measuring the perceived benefit/cost ratios of individual practices, and demonstrating that practices with a high economic benefit/cost ratio are more likely to be adopted. However, the environmental benefits of practices have no influence or possibly even decrease the rate of practice adoption. Even more importantly, there are interaction effects between the perceived benefit/cost ratio and partnership participation and social network ties. This indicates that while partnerships are effective, at least thus far, they are taking advantage of the fact that individually beneficial, under-adopted practices currently exist. Conversely, there is little evidence that partnerships are able to convince growers to adopt practices that require incurring private costs even when environmental benefits are possible via cooperation. Collective action problems will remain a challenge for practices with broad social benefits but high individual costs. One caveat to this finding is that we measured perceived, rather than actual, costs and benefits, using a relative ranking scale. It would certainly be useful for future work to assess the influence of actual costs on adoption and the interaction between participation and actual costs. However, we do think measuring perceived costs and benefits is useful because they are a potentially important proximate influence on decision making.

The results suggest several recommendations for improving sustainability partnerships for agriculture. First, the greater variation observed among practices than among growers suggests that there are certain practices with relatively low rates of adoption that may present opportunities for research and extension via sustainability partnerships. Among the practices with particularly low adoption rates are those with high required investments in capital, knowledge, or time on the part of the grower, or those whose benefits are particularly uncertain. Sustainability partnerships can help build relationships between scientific researchers and practitioners, which can clarify the various costs and benefits of practices and how the practices are best implemented on different types of farming operations. Technological innovations that increase the benefit/cost ratios will accelerate adoption, as long as growers have adequate access to information. Further research is also needed into other attributes of practices other than costs and benefits that may influence adoption rates, and could potentially be leveraged for behavioral change.

Second, our finding that growers respond most to the economic benefits and costs of individual practices and not the environmental benefits suggests that sustainability partnerships need to help growers understand both the economic and environmental effects of practices. Achieving sustainability goals requires identifying practices that provide some economic returns to growers, but also provide environmental or social benefits. Sustainability partnerships can invest in research about how to reduce the costs of practices, and also reduce uncertainty about the potential and long-term benefits. Growers are likely to respond more favorably to partnerships that provide financial justification for adopting sustainable practices. For practices that might achieve environmental benefits if all growers cooperate, but where individual growers incur costs, sustainability partnerships should take steps to build social networks and increase trust among growers that individuals are doing their fair share to address the environmental and social problems of agriculture.

Lastly, the demographic variables included in our analysis lead us to recommend that extension programs should be sensitive to demographic diversity among grower constituents, especially farm size, region, and growers' tenure working in agriculture. Larger scale operations have greater resources, in terms of financial and human capital, to invest in field experimentation and these operations can more easily capitalize on the investment since they can capture the benefits of new practices and technologies over a greater number of acres. Larger scale growers, who are often well-known and embedded in social networks in local agricultural communities, may provide important brokerage roles in research projects and outreach efforts. Geographic region also influenced grower adoption of sustainable practices, which suggests that partnerships working across regional boundaries should take measures to ensure the practices they promote are geographically relevant. To the extent younger growers are more likely to adopt sustainable practices, outreach programs that target early-career growers may be relatively more successful in catalyzing the process of innovation.

Our analysis points out some clear directions for future research. There is a strong need for longitudinal research to untangle the complicated causal pathways linking partnership participation, network formation, and individual decision-making. Unfortunately, implementing such research is costly from the funding perspective, and growers are sometimes reluctant research participants given the many requests they receive to complete surveys and their overall culture of privacy. As with all environmental management research, it is important to ultimately link the adoption of sustainable practices to actual social, environmental, and economic outcomes. Otherwise, the term "sustainable" remains subject to the longstanding criticism that is only a symbolic, normative idea. Expert judgment was used to generate the list of practices examined here, and some of them are backed up by on-farm research. However, the heterogeneity across different types of agricultural operations (i.e., the outcomes from a particular practice might depend on farm-specific variables), along with the fact that outcomes are determined by many variables besides practices, makes analyzing them a challenging task. Lastly, while sustainability partnerships are well-established in viticulture, they are spreading to other crops and regions and it will be important to conduct research on how this species of collaborative governance operates over the broad range of agricultural systems.

6. Acknowledgements

This research was funded by National Science Foundation Grant 0922567, “Social Networks and Decision-Making for Sustainable Agriculture: Cooperation or Innovation?”

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8. Appendix: Model Selection

Table A1 reports, for all 26 models fit to the data, the variables included in the model (indicated by an X in the relevant column), AIC values, differences in the absolute AIC values, and AIC weights. The models are ranked by AIC value, where lower values indicate better fitting models that are expected to make better predictions of future cases. The AIC weights represent the relative likelihood of each model and the top four best fitting models represent virtually 100% of the total weight. The model comparison using AIC indicates partnership participation is the most important predictor of practice adoption. The top 16 models include participation while all lower-ranked models do not. In other words, taking out partnership participation as a predictor variable produces a model with a poorer fit. We use the four top-fitting models (a conservative approach because it includes all models with greater than 0.01 AIC weight) combined to plot predictions for all our variables. All of these top-fitting models contain the variable for partnership participation, underscoring the importance of the variable.

Table A1. Model comparison statistics for 19 candidate models fit to the data. The dependent variable in each model is the adoption decision made by growers about practices. All models include a random intercept for respondent and a random intercept for practice, demographic controls, and various fixed effects for variables of interest. Variables included in each model (by row) are indicated by an X in the relevant cell for each variable (by column). Interaction variables are indicated by an "x" in the column header variable name along with the two variables interacting. The top-four fitting models contain virtually 100% of the AICc weight.

Model	Variables Included in Model						AICc	dAICc	AIC Weight
	Participation	Degree	Benefit / Cost	Participation x Net B/C	Degree x Net B/C	Public Benefit			
1	X	X	X	X	X		22642.9	0.0	0.34
2	X	X	X	X			22643.4	0.5	0.26
3	X	X	X	X	X	X	22643.8	0.9	0.21
4	X	X	X	X		X	22644.3	1.4	0.17
5	X	X	X		X		22650.7	7.8	0.01
6	X		X	X			22650.9	8.0	0.01
7	X		X	X		X	22650.9	8.0	0.01
8	X	X	X		X	X	22651.6	8.7	<0.01
9	X	X	X				22656.6	13.7	<0.01
10	X	X	X			X	22657.5	14.6	<0.01
11	X	X					22663.1	20.2	<0.01
12	X		X				22663.9	21.0	<0.01
13	X	X				X	22664.6	21.7	<0.01
14	X		X			X	22664.8	21.9	<0.01
15	X						22670.4	27.6	<0.01
16	X					X	22672.0	29.1	<0.01
17		X	X		X		22711.1	68.2	<0.01
18		X	X		X	X	22711.1	68.2	<0.01
19		X	X				22717.0	74.1	<0.01
20		X	X			X	22717.0	74.1	<0.01
21		X					22723.6	80.7	<0.01
22		X				X	22725.1	82.2	<0.01
23			X				22741.2	98.3	<0.01
24			X			X	22742.1	99.2	<0.01
25							22742.1	104.9	<0.01
26						X	22749.3	106.4	<0.01

9. Figure captions

Figure 1. Percentage of survey respondents who indicated adoption of a given practice. Practices are grouped into categories. Categories are sorted by average adoption, with the most adopted category listed first.

Figure 2. Predicted probability of adopting a practice (blue lines) and 95% confidence regions (shaded areas) as a function of degree, for three different levels of net costs and benefits. Predictions were generated using AIC-based model averaging from the top four fitted models. The x-axis is scaled to match the range of observations in the data.

Figure 3. Predicted probability of adopting a practice (blue lines) and 95% confidence regions (shaded areas) as a function of degree, for three different levels of net costs and benefits. Predictions were generated using AIC-based model averaging from the top four fitted models. The x-axis is scaled to match the range of observations in the data.