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Coordination of the California Winegrape Supply Chain*

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Abstract

This study investigates factors influencing coordination of the California grape and wine supply chain. Results corroborate prior findings that quality considerations and needs to protect investments in specialized or durable assets significantly increase usage of more formal coordination mechanisms, such as formal contracts and vertical integration or ownership. Consistent with findings for other industries, such investments are associated with greater contract complexity and inclusion of enforcement provisions, while trade partners' prior experience working together decreases contract complexity. Furthermore, our results suggest that quality considerations extend to greater use of formal contracts further downstream. (JEL Classifications: L1, L2, Q13)

Keywords: contracts, grapes, vertical coordination, wine.

I. Introduction

Quality is a key competitive factor in the wine industry, and numerous approaches for organizing and managing the supply chain for winegrapes and wines are employed, ranging from simple oral agreements to formal written contracts to common ownership and management of neighboring stages in the supply chain. Such vertical coordination decisions are considerations of organizational economics (Grossman and Hart, 1986; Williamson, 1975, 1979). Existing studies apply this framework to explain decisions to grow or buy grapes (Fernández-Olmos et al., 2009) and contract grapes or trade them on the cash market (Fraser, 2005; Goodhue et al., 2003), but none comprehensively evaluate both aspects of winegrape supply chains. Findings suggest that uncertainty—for instance, about grape quality—and investments in winegrape and wine production play integral roles in these decisions. Furthermore, contract terms regarding production practices and quality attributes are related to size and experience of the grower and the duration of the relationship with buyers.

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This study revisits vertical coordination of the California winegrape industry for 98 handlers of winegrapes, contributing to a more comprehensive view of the industry by considering a broader array of marketing and procurement decisions than existing studies of established wine regions and providing further insights into grape contract provisions. Prior research on the California winegrape industry considers only contracting decisions of winegrape growers (Goodhue et al., 2003). A broader perspective enables inference of whether the negative impact of some variable on usage of formal contracts, for instance, reflects greater reliance on vertical integration of grape and wine production stages or less formal mechanisms. Winegrape production contributes significantly to the California economy, with a gross production value over $3 billion in 2012 (California Department of Food and Agriculture, 2013), and the California grape and wine industry is an ideal sector for studying vertical coordination for several reasons. Winegrapes are a perishable product, requiring close coordination between growers and wineries at harvest time. Grape quality is critical to a winery's reputation for wine making, which is an important aspect of competition in the industry.[1] Additionally, there is considerable product differentiation along with variation in types of grapes and wines, size of businesses, and vertical coordination mechanisms employed (Goodhue et al., 2003). Factor analytic methods are used to develop measures of growth input and harvest input factors or categories of contract terms, which yield modeling efficiencies in terms of degrees of freedom in regression analysis of procurement and marketing methods (Hair, et al., 1995). The results corroborate previous findings of quality motivations for tighter coordination of winegrape supply chains (Fernández-Olmos et al., 2009; Fraser, 2005; Goodhue et al., 2003) and extend these motivations to wineries' downstream contracting choices, while highlighting how contract provisions protect investments in productive assets that support quality winegrape production.

The paper proceeds as follows. Literature on vertical coordination in wine grape supply chains and organizational theory are reviewed in section II, followed by the research design, including data, measures, and empirical methods employed, in section III. Results are then presented and discussed in section IV, and the paper concludes with implications and suggestions for further research.

II. Relevant Literature and Hypothesis Development

Much of the literature on winegrape supply chains draws heavily on organizational economics (Grossman and Hart, 1986; Williamson, 1975; 1979). With few exceptions (e.g., Chambolle and Saulpic, 2006; Lanette and Steichen, 2010), the research mostly links marketing and procurement decisions to investments supporting grape

[1] The relevance of quality for reputation is well-documented for the wine industry in general (Ashenfelter, 2008; Castriota and Delmastro, 2009; Dubois and Nauges, 2007; Landon and Smith, 1998).

and wine production and to uncertainty regarding quality or grower effort (Fares and Orozco, 2012; Fernández-Olmos et al., 2009; Fraser, 2005; Goodhue et al., 2003).

Goodhue et al. (2003) find that use of written contracts by winegrape growers in California is significantly more likely for producers of high-quality grapes, as approximated by price, years in business, years working with buyers, and acreage. For larger producers and those raising higher-quality grapes, the value of potentially appropriable quasi-rents is large enough to justify the costs of contracting. Notably, written contracts for higher-quality grapes are more likely to include provisions regarding the production process, while written contracts for lower-quality grapes are more likely to include financial incentives for particular attributes, such as sugar content.

Similarly, in Australia, Fraser (2005) finds a higher probability of use of written contracts among larger and more experienced grape growers. The study also finds that the probability a contract includes various stipulations regarding grape quality, yield, and production practices increases with contract duration, but stipulations regarding production practices in particular decrease with the length of the trade relationship, possibly reflecting development of trust or growers' familiarity with wineries' needs. Fraser (2005) also identifies that contracts in lower-quality-grape growing regions rely more on grape quality assessment, while those in higher-quality regions place greater emphasis on winery involvement and direction in vineyard management, which parallels the findings of Goodhue et al. (2003).

Fernández-Olmos et al. (2009) find that Spanish wineries' choices to grow rather than buy most grapes are positively related to wine quality (i.e., wine differentiation of *reserva* and *crianza* wines from *guarantee of origin* wines), investments in specialized assets dedicated to grape growing and the level of behavioral and environmental uncertainty involved. The authors suggest that a lack of statistical significance for investments in assets supporting winemaking reflects that wineries' revenues are increasingly not just from winemaking but also from wine tourism. Vertical integration is negatively related to size, as proxied by average capacity from 2002 to 2004, perhaps due to a need to source large amounts of grapes. The authors conclude by calling for more comprehensive research across the full spectrum of modes of exchange.

Fares and Orozco (2012) find that a French wine cooperative's tournament contract pricing mechanism complements imperfect grape quality measurement and task monitoring by field staff by incentivizing heterogeneous grower-owners to reveal productive capabilities of vineyards and exert (optimal) effort toward production quality. Specifically, growers reveal productive capabilities by choosing between contracts for three quality levels of grapes. The promise of promotion to or maintenance in the high-quality category incentivizes performance for higher-quality grapes, while monitoring enhances quality in the lower-quality category.

Table 1
Respondents' Rankings of Top Four Quality Attributes Measured

Quality Attributes	*Most Important*	*2nd*	*3rd*	*4th*
Objective Attributes				
Sugar content (brix)	41%	17%	15%	4%
Acidity (ph)	0%	21%	40%	30%
Rot/Mold	3%	15%	12%	10%
MOG	0%	2%	6%	8%
Subjective Attributes				
Flavor/Taste	20%	6%	1%	5%
Ripeness/Maturity	10%	7%	1%	0%
Visual/Color	4%	7%	4%	9%

Source: Calculated by author using data from Hueth et al. (2007). Data available at www.aae.wisc.edu/hueth/calag.zip (accessed March 18, 2013).
Notes: $n = 98$. MOG = "material other than grapes."

Wineries, like other businesses, seek to increase sales via product differentiation, which leads to heterogeneity of input needs across wineries. Such businesses may then implement their own grading standards and corresponding quality premiums to source inputs with quality attributes that support their differentiation strategy (Jang and Olson, 2010; Jang and Sykuta, 2008) or, alternatively, may produce inputs in-house. External suppliers may require having these terms in writing to serve specific winery needs. Therefore, we hypothesize:

Hypothesis 1: Buyer measurement of quality is positively associated with sophistication of procurement mechanism.

Hypothesis 2: Quality premiums are positively associated with use of formal contracts.

Financial incentives may adequately ensure performance on objectively measurable or quantifiable attributes, such as sugar (i.e., degree brix) or acidity, but less easily measured subjective quality attributes, such as grape appearance or color and taste or flavor are also important, as documented in Table 1. According to organizational economics literature, if quality is imperfectly measurable, or measurable only at high cost, then contract provisions can stipulate *best practices* known to deliver desired quality levels, presuming their use is easily verified—that is, the task is highly programmable. Formal written contracts facilitate third-party (i.e., court) enforcement, encouraging adherence to agreed-upon contract terms (Mahoney, 1992). If both quality is difficult to measure and production practices do not correlate with quality or are not easily verified, in-house production may be necessary. We hypothesize:

Hypothesis 3: Measurement difficulty is positively associated with the use of formal contracts.

Thus, specification or provision of specific production inputs may assist in ensuring quality. That is, wineries and other buyers of grapes may secure desired types and quality levels using contracts with language directing or precluding growers' use of certain grape varietals, insecticides, fertilizers, and pruning and picking practices. Gergaud and Ginsburgh (2008) show that technological choices (i.e., grape varietals, picking and fermenting technologies) affect quality much more than natural endowments (i.e., land characteristics and exposures of vineyards). Furthermore, buyers using contracts to coordinate the quality of grapes procured may also grow some themselves to ensure adequate supply of quality grapes. Hence, we expect:

Hypothesis 4: Buyer specification or provision of inputs for growing and harvesting grapes is positively associated with sophistication of exchange mechanism.

Input specification or provision may ensure quality but may also entail investment in specialized or durable assets by either the supplier, the buyer, or both. In particular, specification of production inputs requires such investments on the part of the supplier, whereas provision of inputs implies investments on the part of the buyer.

Reuer and Arino (2007) found that the complexity (i.e., number of provisions) of alliance contracts across several industries in Spain is significantly greater in the presence of such investments and significantly lower when prior ties exist among contracting parties. The costs of writing more complex contracts that cover dispute resolution procedures and consequences of breach and termination become worthwhile to protect the potentially appropriable quasi-rents stemming from these investments. In contrast, prior experience working together engenders trust and development of interorganizational routines and a better understanding of one another's needs, procedures, management systems, cultures, and so on. Looking more closely at the type of provisions included in contracts, Reuer and Arino (2007) identify that asset specificity significantly increases the use of enforcement provisions designed to safeguard quasi-rents, while prior ties significantly decrease the need for basic coordination provisions but not enforcement provisions. Hence, we hypothesize:

Hypothesis 5: Buyer specification or provision of inputs for growing and harvesting grapes is positively associated with contract complexity and enforcement provisions in particular.

Hypothesis 6: Duration of trade relationship in years is negatively associated with contract complexity and coordination provisions in particular.

These hypotheses are empirically tested as described in the research design section.

III. Research Design

A. Research Context

We analyze data on the proportion of grapes produced in-house or procured via formal or informal contracts by 98 winegrape handlers. The data are from a 1999 survey of 385 handlers of fruit, vegetable, and nut commodities in California (Hueth et al., 2007). Data from a pilot study for the survey instrument are reported in Hueth and Ligon (1999). Responses to an open-ended question about the firms' activities reveal that at least 70% are involved with grape production and 43% make wine. Whereas previous studies have focused on exchange of grapes between grower and winery, the available data allow us to also examine subsequent downstream transactions (i.e., how survey respondents sell grapes or wine).

B. Measures

Variables and summary statistics are presented in Table 2. Procurement and marketing methods (i.e., *In-House Production, Formal Contract*, and *Informal Contract*) are measured as the percentage of grapes traded via that method. Indices are also developed to capture the degree of formality involved. *Grower Formality* is an index computed by multiplying percentages of grapes procured via in-house production by three, via formal contracts by two, via informal contracts by one, and via other methods (e.g., cash or cooperative) by zero. Correspondingly, *Buyer Formality* is an index computed by multiplying percentages of grapes or wine marketed via formal contracts by two, via informal contracts by one, and via cash sales by zero.

Following Reuer and Arino (2007), *Contract Complexity* is the number of provisions in the contract or arrangement, as selected by survey respondents from a predefined list including the number of acres, adjustment for quality, provisions governing quality measurement, target date of delivery, provisions for governing contract renewal, compensation (e.g., method of calculating payment to grower, volume (e.g., tons, bushels, or other production units), and means of negotiating disputes (e.g., appeal procedure). Hence, contract complexity may range in value from one provision to eight provisions.

Factor analysis of survey items is used to limit error in measurement of variables representing certain types of contractual provisions and buyer requirements for grape production inputs (Bollen, 1989; Hair et al., 1995; Thompson, 2004). Survey respondents selected inputs that they provided or required growers to use from a predefined list, including fertilizer, pesticides, plants, labor, and equipment. Relationships between relevant items are summarized as a smaller set of more parsimonious variables (eigenvectors called factors) that conserve degrees of freedom and improve power against Type II error in subsequent regression analyses (Thompson, 2004). Following the conventional "K1" rule, we identify notable factors possessing characteristic roots (eigenvalues) greater than one (Thompson, 2004). Survey items loading nearly evenly on multiple factors were eliminated to preserve unidimensionality of factors. (Complete results are available from authors upon request.) The analysis yields two factors pertaining to input requirements—*Growth Inputs* comprising fertilizers, pesticides, and plants and *Harvest Inputs* consisting of equipment and labor—and two factors regarding

Table 2
Variable Definitions and Summary Statistics

Variable	N	*Mean*	*Standard Deviation*	*Min*	*Max*	*Description*
Grape procurement methods:						
In-House Production	102	22.99%	26.02%	0.00%	90.00%	% grown by own firm
Formal Contract	102	55.08%	34.45%	0.00%	100.00%	% procured by formal contracts
Informal Contract	102	21.37%	32.66%	0.00%	100.00%	% procured by informal contracts
Grower Formality	102	2.01	0.49	0.96	2.90	= 3 × In-House Production + 2 × Formal Contract + 1 × Informal Contract + 0 × Other
Procurement contract provisions:						
Complexity	105	4.65	2.06	0.00	8.00	Number of contract provisions selected
Dispute	105	0.49	0.50	0.00	1.00	= 1 if dispute resolution provision, otherwise = 0
Renewal	105	0.61	0.49	0.00	1.00	= 1 if renewal provision, otherwise = 0
Quality	105	0.62	0.49	0.00	1.00	= 1 if quality adjustment provisions, otherwise = 0
Delivery	105	0.20	0.40	0.00	1.00	= 1 if delivery target date provision, otherwise = 0
Marketing methods:						
Formal Contract	103	48.23%	42.52%	0.00%	100.00%	% sold by formal contracts
Informal Contract	102	30.25%	38.71%	0.00%	100.00%	% sold by informal contracts
Buyer Formality	102	1.26	0.65	0.00	2.00	= 2 × Formal Contract + 1 × Informal Contract + 0 × Spot
Independent variables:						
Years	105	25.40	23.65	2.00	127.00	Years in business
Sales %	104	97.01%	9.47%	20.00%	100.00%	% of sales attributable to grapes/wine
Retail	102	14.59%	21.81%	0.00%	80.00%	% of grapes/wine purchased by retailers
Wholesale	102	9.12%	16.48%	0.00%	80.00%	% of grapes/wine purchased by wholesalers
Direct	101	56.15%	33.86%	0.00%	100.00%	% of grapes/wine purchased by consumers
Export	92	18.31%	23.24%	0.00%	100.00%	% of grapes/wine exported
Other	100	10.28%	18.32%	0.00%	90.00%	% of grapes/wine purchased by others
Sacramento	105	0.17	0.38	0.00	1.00	= 1 if growers in Sacramento, otherwise = 0
San Joaquin	105	0.16	0.37	0.00	1.00	= 1 if growers in San Joaquin, otherwise = 0
Central Coast	105	0.39	0.49	0.00	1.00	= 1 if growers in Central Cost, otherwise = 0
Other Region	105	0.28	0.45	0.00	1.00	= 1 if growers in Other region, otherwise = 0
Self-Measurement	105	0.90	0.31	0.00	1.00	= 1 if use own measurement, otherwise = 0
Govt. Measurement	105	0.05	0.21	0.00	1.00	= 1 if use government measurement, otherwise = 0
Third-Party Measurement	103	0.13	0.33	0.00	1.00	= 1 if use third-party measurement, otherwise = 0
Measurement Difficulty	100	2.30	0.73	1.00	4.00	Scale: 1 (poorly) to 5 (perfectly) measure grape quality attributes
Quality Premium	102	0.55	0.50	0.00	1.00	= 1 if pay grower a quality premium, otherwise = 0
Duration of Relationship	100	65.78	27.09	6.00	120.00	weighted number of years working with growers
Tons Bought	101	2,729.14	12,999.25	7.00	110,000.00	Tons of grapes purchased

Source: Calculated by author using data from Hueth et al. (2007). Data available at www.aae.wisc.edu/hueth/calag.zip (accessed March 18, 2013).
Notes: "Other Region" includes the North Coast and Napa Valley.

contract stipulations—*Enforcement Provisions* comprising contract renewal and dispute resolution and basic *Coordination Provisions* comprising delivery date and quality adjustments. Cronbach's (1951) alphas of 0.70 and 0.67, respectively, indicate that measures of harvesting inputs and enforcement provisions are fairly reliable, while values of 0.57 and 0.39 indicate relatively less reliable measurement of growth inputs and coordination provisions, respectively (Streiner and Norman, 1995).

Several explanatory variables are measured directly by survey items. *Years* is how long the respondent's company has been in business and approximates experience or tenure. *Duration of Relationship* is the years of experience with growers, on average. *Sales %* is the percentage of revenues from grape or wine sales and represents the importance of this activity to the company. *Tons Bought* (of grapes) is a reflection of company size. *Measurement Difficulty* is the reverse coding of survey participants' responses on a Likert scale of 1 (poorly) through 5 (perfectly) to the question "How well does what you measure capture all relevant quality attributes (for grapes)?" Finally, several binary variables (equal to one if yes and zero if no) indicate region of operation, the types of buyers (retail, wholesale, institutional, direct, export, etc.) that the respondent supplies, whether grower compensation is conditional on quality (i.e., *Quality Premium*), and who measures quality (i.e., respondent, government, or another third party). The design of the survey of handlers of fruits, vegetables, and nuts designates general regions of agricultural production in California and, as such, major wine-producing regions (i.e., Napa Valley and the Northern Coast) happen to be in the other region category. While this designation seems a bit odd, omission of the binary other region variable in regression analysis enables testing for evidence of the small numbers bargaining problems in the San Joaquin region identified by Goodhue et al. (2003), thereby facilitating comparison with their observations.

C. Modeling Marketing Behavior

Estimation procedures employed here follow directly from Katchova and Miranda (2004). Some studies of winegrape supply chains examine whether contracts are employed using binary (i.e., logit or probit) models (Fraser, 2005; Goodhue et al., 2003). Modeling proportional usage of marketing/procurement methods is more informative. For instance, Fernández-Olmos et al. (2009) examine wineries' degree of reliance on their own estate vineyards using Tobit models. The Tobit log-likelihood contains probabilities of nonuse from a probit regression in the first term and a classical regression for positive values in the second (Katchova and Miranda, 2004):

$$\ln L = \sum_{\alpha_i=0} \ln \Phi\left(-\frac{\beta'_\alpha x_i}{\sigma}\right) + \sum_{\alpha_i>0} \ln\left[\frac{1}{\sigma}\phi\left(\frac{\alpha_i - \beta'_\alpha x_i}{\sigma}\right)\right], \tag{1}$$

where $\Phi(\bullet)$ is the standard normal probability density function, $\mathbf{x}_i$ and β_α are vectors of independent variables and coefficients, σ is the standard deviation, and α_i denotes the proportion contracted.[2] Under the Tobit formulation, the independent variables and associated coefficients are constrained to be the same for the contract adoption and proportion contracted decisions.

Katchova and Miranda (2004) argue that Cragg's (1971) less restrictive hurdle or two-step model, which does not require variables and coefficients for both decisions to be the same, is more consistent with the sequential progression of the actual decision making process (i.e., adoption decision followed by proportional usage decision). Following Katchova and Miranda (2004), the log-likelihood is the sum of the log-likelihood of a probit regression (the first two terms) and the log-likelihood of a truncated regression (the second two terms) and is given by

$$\ln L = \sum_{c_i=0} \ln \Phi(-\gamma' z_i) + \sum_{\alpha_i>0} \left\{ \ln \Phi(\gamma' z_i) + \ln\left[\frac{1}{\sigma}\phi\left(\frac{\alpha_i - \beta'_\alpha x_i}{\sigma}\right)\right] - \ln \Phi\left(\frac{\beta'_\alpha x_i}{\sigma}\right)\right\}, \quad (2)$$

where $\mathbf{z}_i$ and γ are vectors of independent variables and coefficients pertaining to contract adoption and, as before, $\mathbf{x}_i$ and β_i are vectors of independent variables and coefficients pertaining to the proportion contracted. When $\mathbf{z}_i = \mathbf{x}_i$ and $\gamma = \beta_\alpha/\sigma$, Equations (1) and (2) are equivalent. The hurdle model is intuitive for cases where choices of adoption and proportional use are made sequentially. From a practical standpoint, Tobit models seem particularly appropriate when (nearly) all observations in the sample are indicative of use or adoption or when dependent variables are indices reflecting a continuum but not an adoption/non-adoption (i.e., yes/no) component, such as the *Grower Formality* and *Buyer Formality* variables. In cases where normality of Tobit residuals is violated, Powell's (1984) censored least absolute deviations (CLAD) estimator is a viable alternative. CLAD is robust to heteroskedasticity and is consistent and asymptotically normal for a wide class of error distributions.

IV. Results

A. Grape Procurement Methods

The marginal effects of a Tobit regression of the *Grower Formality* index, representing the relative formality of grape procurement arrangements employed, and hurdle models, consisting of binary probit and truncated ordinary least squares (OLS) regressions, for each procurement method are presented in Table 3. The Shapiro and Wilk (1965) test cannot reject the null hypothesis of normality of residuals from the Tobit regression at conventional levels, supporting this modeling decision. Following Katchova and Miranda (2004), we report results from a Tobit regression censored only at the lower limit, but a two-limit Tobit regression yields

[2] The proportion contracted α_i equals the latent variable $\alpha_i{}^*$ for $\alpha_i{}^* = \beta'_\alpha X_i + \varepsilon_{\alpha i} > 0$ and equals zero otherwise, where $\varepsilon_{\alpha i}$ are independently and normally distributed residuals with mean zero and variance σ^2.

Table 3
Regression Results for Grape Handler Procurement Method

	Grower Formality	*In-House Production*		*Formal Contract*		*Informal Contract*	
	Tobit	*Probit*	*Trunc OLS*	*Probit*	*Trunc OLS*	*Probit*	*Trunc OLS*
Years	0.006**	0.011**	0.008***	−0.002*	−0.003*	−0.005	0.010**
	(0.003)	(0.004)	(0.003)	(0.001)	(0.002)	(0.003)	(0.005)
Sales %	0.496	−0.914	−0.810	0.208	0.612	−1.916	−0.785
	(1.021)	(1.517)	(0.991)	(0.237)	(0.637)	(1.553)	(0.878)
Buyer:							
Retail	0.295	−0.571	−0.485	0.057	0.496**	−1.083**	−0.131
	(0.363)	(0.493)	(0.522)	(0.208)	(0.205)	(0.534)	(0.401)
Wholesale	0.168	−0.336	0.194	−0.019	0.207	−0.668*	0.136
	(0.239)	(0.330)	(0.323)	(0.120)	(0.140)	(0.364)	(0.211)
Direct	0.002	−0.189	0.132	−0.131	−0.166	−0.226	0.038
	(0.275)	(0.370)	(0.324)	(0.131)	(0.180)	(0.499)	(0.291)
Export	0.624	−0.513	2.209	–	−0.661	−0.357	−2.054
	(1.073)	(1.293)	(1.429)		(0.597)	(1.632)	(1.543)
Region:							
Sacramento	−0.068	0.262**	0.405*	–	−0.364***	0.068	−0.019
	(0.170)	(0.108)	(0.232)		(0.096)	(0.241)	(0.262)
San Joaquin	−0.171	−0.231	−0.579**	0.049	0.284***	0.222	−0.991***
	(0.165)	(0.252)	(0.244)	(0.038)	(0.092)	(0.226)	(0.356)
Central Coast	−0.027	−0.185	−0.048	0.030	0.048	0.058	0.203*
	(0.102)	(0.138)	(0.131)	(0.045)	(0.061)	(0.148)	(0.119)
Buyer Contract	0.366***	0.150	0.197	0.117	0.131*	−0.427**	−0.782***
	(0.117)	(0.149)	(0.144)	(0.077)	(0.070)	(0.183)	(0.177)
Growth Inputs	0.182***	0.156*	−0.026	0.061	0.034	−0.131	−0.314***
	(0.057)	(0.083)	(0.065)	(0.038)	(0.036)	(0.084)	(0.086)
Harvest Inputs	−0.031	0.099	−0.020	0.016	−0.013	−0.043	0.111**
	(0.058)	(0.082)	(0.073)	(0.029)	(0.035)	(0.082)	(0.051)
Self-Measurement	0.095	0.474*	0.955**	–	−0.282**	−0.004	0.288
	(0.207)	(0.287)	(0.422)		(0.113)	(0.306)	(0.353)
Third-Party	−0.087	−0.372	0.032	–	−0.052	0.147	−0.202
Measurement	(0.153)	(0.230)	(0.221)		(0.087)	(0.221)	(0.185)
Measurement	0.095	0.113	−0.153*	−0.005	0.117***	−0.290**	0.098
Difficulty	(0.069)	(0.095)	(0.083)	(0.037)	(0.038)	(0.118)	(0.115)
Quality	−0.022	−0.098	0.077	−0.077	0.111*	−0.118	0.059
Premium	(0.100)	(0.123)	(0.118)	(0.056)	(0.061)	(0.140)	(0.106)
Duration of Relationship	−0.003*	−0.002	0.002	−0.003**	0.000	0.001	−0.001
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.002)
Sigma:	–	–	0.257***	–	0.213***	–	0.206***
Constant			(0.044)		(0.019)		(0.028)
R^2	0.2759	0.2144	–	0.3808	–	0.2312	–
N	81	81	55	90	69	81	41
Truncated	–	–	26 at 0	–	12 at 0	–	40 at 0
Left censored	1 at 0.959	–	–	–	–	–	–

Source: Author's model results.
Notes: ***, **, * significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. Hurdle models consist of Probit and Truncated OLS (Trunc OLS).

qualitatively similar results. Recall that hurdle models correspond to sequentially made adoption and proportional usage decisions and, unlike Tobit models, do not restrict any particular explanatory variable to have the same effect on both decisions (Katchova and Miranda, 2004). Regressions are run in STATA, which automatically dropped some binary dummy variables from binary probit regressions in cases where these explanatory variables perfectly predict the dependent variable. Dropping these variables has no effect on the likelihood or estimates of remaining coefficients and increases the numerical stability of the optimization process (STATA, 2013, p. 1669). Most of the variables of interest remain intact in the results presented here.

Several of the results for grape procurement methods are consistent with previous research (Table 3). Goodhue et al. (2003) find that more experienced winegrape growers in California are significantly more likely to sell through formal contracts than through informal contracts. Here, *Years* in business also significantly increases usage of more formal procurement methods, reflecting greater use of in-house production and less use of formal contracts. Specifically, hurdle model results indicate that ten additional years in business over the mean of 25 years increases the probability of in-house production by 11% (i.e., probit results) and its proportional use by 8% (i.e., truncated OLS results), while decreasing the probability of using formal contracts by 2% and their proportional use by 3%. Although adoption of informal contracts is not influenced by *Years* (i.e., probit results), *Years* increases proportional usage among adopters (i.e., truncated OLS results), suggesting that grape handlers who use informal contracts become comfortable relying more heavily on them with time and experience. Interestingly, as sales of grapes and wine become an increasingly important component of the business (i.e., *Sales %*), proportional use of formal contracts decreases significantly, but a lack of significant effects in other regressions provides no indication of which procurement methods are used in its place.

Regional dummies' coefficients indicate greater use of in-house production and less proportional use of formal contracts among growers in the Sacramento Valley compared to an excluded *other region* category that predominately represents major wine-producing regions—Napa Valley and the Northern Coast (Table 3). In-house production and informal contracts are used proportionally less and formal contracts proportionally more among growers in the San Joaquin Valley. Because relatively fewer wineries are in the San Joaquin region than in major wine regions in the other region category (Goodhue et al., 2003), few alternative buyers pose a small-numbers problem for growers as a motivation for formal contract use (Williamson, 1975). That is, with fewer buyers of perishable grapes, a winery could potentially renege on an informal agreement with a grower or accept delivery only at a lower price than previously agreed upon.

Relative to the baseline of an institutional buyer (i.e., food service or restaurants), having a retail buyer (i.e., supermarket or grocer) significantly increases proportional use of formal contracts and decreases adoption of informal contracts (Table 3). Except for the negative effect of wholesale buyers on adoption of informal contract methods, none of the other binary dummies for buyer type are statistically significant. The result is somewhat surprising for the export buyer dummy, in particular, as evidence from the French wine industry (Crozet et al., 2012) suggests a positive relationship between wine quality and exporting (i.e., producers of high-quality wine export to more markets). If quality control requires tighter coordination, exporting wineries may be expected to utilize such practices more so than those selling only domestically. Another binary dummy variable indicates that use of formal contracts with buyers makes grape handlers significantly more reliant on formal contracts with growers and significantly less reliant on informal contracts. This result may reflect use of formal arrangements to coordinate exchange of higher quality products along the entire supply chain.

Relative to the baseline of quality measurement by government entities like the United States Department of Agriculture, grape handlers that ascertain the quality of growers' grapes themselves are 47% more likely to also produce their own grapes and rely 96% more on their own production (Table 3). This finding directly supports H1. Grape handlers that offer growers financial incentives for quality source about 11% more of their grapes using formal contracts than those not offering quality premiums, which is consistent with H2.

Measurement Difficulty, or the degree to which grape handlers' quality measurement procedures capture all relevant characteristics (i.e., 1 = perfectly to 5 = poorly), is also significantly related to use of formal and informal contracts (Table 3). Specifically, a unit increase in perceived measurement difficulty above the mean of 2.30 decreases the probability of using informal contracts by 29% and increases proportional use of formal contracts 12%, which supports H3. When accurately measuring quality is difficult, stipulation of best practices may help to ensure quality (Mahoney, 1992). Such terms may require specific investments by either of the parties to the exchange, prompting employment of formal contractual safeguards or vertical integration (i.e., ownership) of both stages of the supply chain to protect the value of these investments.[3] While grape handler specification or provision of *Harvest Inputs* (i.e., labor and equipment) is positively related to proportional use of informal contracts, specification or provision of *Growth Inputs* (i.e., fertilizer, pesticides, and plants) has a negative impact. Additionally, *Growth Inputs* has a nearly significant positive effect on the probability of using formal contracts ($p = 0.105$) and a significantly positive effect on the probability of in-house grape production. The latter result implies that grape handlers that stipulate the use of certain growth inputs in contracts with growers are also more likely to produce at least some grapes themselves. These findings are consistent with H4. Interestingly,

[3] Fernández-Olmos et al. (2009) find that growers' but not wineries' investments in dedicated and specialized assets significantly increase the probability of vertical integration of vineyard and winery stages of the supply chain. Our data do not allow us to distinguish whether such investments were made by growers or buyers.

the results also suggest that the need for formal contracts to protect trade partners' relative interests declines with experience trading with each other, as evidenced by the negative impact of the *Duration of Relationship* variable in probit models of formal contract use. This point is explored further in terms of contractual provisions in the following section.

B. Grape Procurement Contract Provisions

Regressions of the number and type of contract provisions are presented in Table 4 for a subsample of grape handlers using formal contracts and in Table 5 for a larger subsample using formal or informal contracts. Most informal contracts deal predominately with volume and compensation, but some grape handlers orally agree to certain stipulations regarding quality and contract renewal, for instance. As discussed below, except for scale effects (i.e., *Tons Bought*) and the influence of the *Duration of the Relationship*, the results are fairly similar across these subsamples. *Contract Complexity* (i.e., number of contract provisions) is modeled using a count regression assuming a Poisson distribution. A goodness-of-fit (deviance) test, following Cressie and Read (1984), supports the assumption of Poisson distribution. Qualitatively similar results are obtained from a Tobit regression for which the Shapiro and Wilk (1965) test rejects the null hypothesis of normality of residuals at the 5 percent level but not at the 1 percent level. This test rejects the null hypothesis of normality of residuals at the one percent level for Tobit regressions of continuous *Enforcement* and *Quality Coordination* factors. Hence, censored least absolute deviations (CLAD) estimation (Powell, 1984), which is robust to heteroskedasticity and is consistent and asymptotically normal for a wide class of error distributions, is used instead. Finally, binary probit regressions provide insight into the probability that specific types of provisions or contract terms are stipulated. The low explanatory power (R^2) of these regressions suggests opportunities for future research to better explain the variation in contract complexity and use of such provisions.

The results for *Growth Inputs* are generally consistent with Reuer and Arino's (2007) findings across several industries and support H5. Specifically, grape handler provision or specification of *Growth Inputs* significantly increases the complexity of contracts and the probability that certain contract provisions are included (Tables 4 and 5). Meeting such stipulations for *Growth Inputs* may require specific investments by either of the parties to the contract and, hence, may be expected to increase the number of contract provisions and the use of *Enforcement* provisions, such as procedures for *Dispute* resolution and terms of contract *Renewal*. Here, it is important to note that these results appear to be driven by inclusion of such terms mostly in formal written contracts, for which third-party (i.e., court) enforcement is easier than under informal agreements.

Reuer and Arino (2007) suggest that their finding of lower use of coordination provisions among trade partners with prior ties reflects development of trust and knowledge of each other's needs and procedures over time, reducing the need for

Table 4

Regressions of Formal Contract Provisions

Variable	*Contract Complexity Poisson*	*Enforcement CLAD*	*Quality Coordination CLAD*	*Dispute Probit*	*Renewal Probit*	*Quality Probit*	*Delivery Probit*
Growth Inputs	0.533*	0.314**	−0.004	0.116*	0.134*	0.088	−0.025
	(0.282)	(0.128)	(0.080)	(0.068)	(0.073)	(0.064)	(0.054)
Harvest Inputs	0.129	0.287	−0.048	0.064	−0.015	−0.043	−0.059
	(0.296)	(0.239)	(0.158)	(0.066)	(0.065)	(0.059)	(0.062)
Duration of Relationship	−0.008	−0.010	0.002	−0.002	−0.002	0.002	−0.001
	(0.009)	(0.008)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Years	0.000	0.007	−0.004	0.001	−0.001	−0.002	−0.001
	(0.012)	(0.011)	(0.008)	(0.003)	(0.003)	(0.002)	(0.002)
Sales %	2.839	2.156	−0.211	0.175	21.706*	−0.959	−0.215
	(2.754)	(1.975)	(2.384)	(0.575)	(1.028)	(0.904)	(0.451)
Tons bought	2.340×10^{-5}	5.90×10^{-6}	1.84×10^{-6}	5.720×10^{-5}	1.310×10^{-5}	3.080×10^{-5}	-2.430×10^{-6}
	(2.000×10^{-5})	(5.61×10^{-5})	(5.71×10^{-5})	(3.000×10^{-5})	(2.000×10^{-5})	(3.000×10^{-5})	(1.000×10^{-5})
R^2	0.0178	0.1184	0.0108	0.0831	0.0969	0.0854	0.0304
N	84	84	84	84	84	84	84
Left censored	–	4 at 0.000	2 at 0.000	–	–	–	–

Source: Author's model results.

Notes: ***, **, * significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. CLAD = censored least absolute deviations regression.

Table 5

Regressions of Formal and Informal Contract Provisions

Variable	*Contract Complexity Poisson*	*Enforcement CLAD*	*Quality Coordination CLAD*	*Dispute Probit*	*Renewal Probit*	*Quality Probit*	*Delivery Probit*
Growth Inputs	0.713***	0.388***	0.058	0.128**	0.176**	0.152**	0.008
	(0.242)	(0.142)	(0.153)	(0.065)	(0.074)	(0.067)	(0.048)
Harvest Inputs	0.116	0.373*	−0.053	0.071	−0.009	−0.046	−0.068
	(0.262)	(0.207)	(0.165)	(0.063)	(0.064)	(0.060)	(0.059)
Duration of Relationship	−0.018**	−0.016**	1.337×10^{-4}	−0.003	−0.004**	−0.001	−0.002
	(0.008)	(0.007)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)
Years	0.003	0.008	-2.386×10^{-4}	3.720×10^{-4}	−0.002	−0.001	0.001
	(0.009)	(0.009)	(0.013)	(0.002)	(0.002)	(0.002)	(0.002)
Sales %	2.841	2.508	−0.107	0.313	2.126*	−0.711	−0.240
	(2.460)	(1.603)	(2.874)	(0.560)	(1.098)	(0.740)	(0.412)
Tons bought	2.620×10^{-5}*	8.97×10^{-6}	1.62×10^{-7}	7.120×10^{-5}**	3.580×10^{-5}	4.430×10^{-5}	-3.400×10^{-6}
	(1.000×10^{-5})	(3.46×10^{-5})	(1.33×10^{-4})	(3.000×10^{-5})	(3.000×10^{-5})	(3.000×10^{-5})	(1.000×10^{-5})
R^2	0.0373	0.1167	0.0005	0.1074	0.1327	0.1012	0.0421
N	97	97	97	97	97	97	97
Left censored	–	6 at 0.00	2 at 0.000	–	–	–	–

Source: Author's model results.
Notes: ***, **, * significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. CLAD = censored least absolute deviations regression.

some contract terms. Here, *Duration of Relationship* significantly decreases the complexity of contracts in the subsample of grape handlers using either formal or informal contracts (Table 5), supporting H6. The same effect is not apparent in the results for the subsample of grape handlers using formal contracts (Table 4). Hence, it appears that if trust and familiarity are gained over time, then the need for certain provisions and the enforcement power of formal contracts in general declines (Tables 3 and 5). Like Reuer and Arino (2007), we also find that firm size (i.e., *Tons Bought*) significantly increases contract complexity (Table 5), which may reflect greater use of contractual safeguards among large firms and those that rely heavily on formal contracts.

C. Grape and Wine Marketing Methods

Regression results explaining the methods used by grape handlers to market grapes or wine are presented in Table 6. To our knowledge, prior research has not addressed this segment of the grape/wine supply chain. The Shapiro and Wilk (1965) test rejects the null hypothesis of normality of residuals from a Tobit regression of the *Buyer Formality* index at the 1 percent level, so CLAD estimation is again employed to arrive at consistent estimates (Powell, 1984). Each marketing method underlying the *Buyer Formality* index is examined using hurdle models (i.e., binary probit followed by truncated OLS), as Katchova and Miranda (2004) have established that decisions regarding amounts marketed via particular methods are made conditionally on, not jointly with, decisions to adopt those methods.

The most interesting results are related to buyer type, procurement method, and quality considerations (Table 6). Specifically, grape handlers that sell to retail (e.g., supermarkets) or wholesale (e.g., brokers, processors, shippers) buyers use formal contracts for over 40% more of their sales. Those that grow their own grapes or procure them via formal contracts use informal contracts less and formal contracts more when marketing. Quality appears to be relevant across the entire supply chain, as the use of quality premiums with growers significantly decreases the probability of using informal contracts with buyers by 25%, and correspondingly, has a positive though not conventionally significant effect ($p = 0.116$) on adoption of formal contracts.

V. Conclusions

This study investigates factors that influence the use of alternative approaches to coordinating exchange within the California grape and wine supply chain. Prior research has examined Spanish wineries' decisions to make or buy grapes (Fernández-Olmos et al., 2009) and California grape growers' use of formal and informal contracts (Goodhue et al., 2003). We offer a more comprehensive analysis of the supply chain from vineyards to wineries' customers. In particular, we present the first study, to our knowledge, to examine the use of formal and informal

Table 6
Regression Results for Grape Handler Marketing Method

	Buyer Formality	*Formal Contract*		*Informal Contract*	
	CLAD	*Probit*	*Trunc OLS*	*Probit*	*Trunc OLS*
Years	0.002	0.005	0.001	−0.005	−0.005
	(0.006)	(0.004)	(0.002)	(0.004)	(0.005)
Sales %	2.907	−0.198	0.882	−1.176	2.318*
	(1.890)	(1.160)	(0.777)	(1.354)	(1.335)
Buyer:					
Retail	0.034	−0.518	0.469*	−0.602	0.862*
	(0.821)	(0.436)	(0.270)	(0.565)	(0.490)
Wholesale	0.342	−0.300	0.427**	−0.688*	0.339
	(0.542)	(0.287)	(0.180)	(0.404)	(0.315)
Direct	−0.519	−0.098	−0.305	−0.771	0.378
	(0.879)	(0.324)	(0.205)	(0.528)	(0.396)
Export	0.555	−1.493	0.320	−0.378	3.392**
	(3.089)	(1.331)	(0.714)	(1.558)	(1.727)
Region:					
Sacramento	0.008	−0.130	0.016	0.295*	0.038
	(0.371)	(0.204)	(0.105)	(0.161)	(0.180)
San Joaquin	−0.068	0.120	−0.180	0.371***	−0.229
	(0.412)	(0.179)	(0.122)	(0.143)	(0.240)
Central Coast	−0.119	0.010	0.024	−0.227	−0.008
	(0.250)	(0.118)	(0.072)	(0.145)	(0.139)
Grow Ourselves	0.802	0.596**	0.348*	−0.984***	−0.392
	(0.491)	(0.250)	(0.190)	(0.344)	(0.255)
Grow Contract	0.873***	0.550***	0.411***	−1.260***	−0.468**
	(0.316)	(0.194)	(0.161)	(0.300)	(0.212)
Quality Premium	0.097	0.182	−0.014	−0.246*	−0.056
	(0.210)	(0.115)	(0.073)	(0.139)	(0.116)
Sigma: Constant	–	–	0.247***	–	0.313***
			(0.025)		(0.045)
R^2	0.1521	0.1783	–	0.3211	–
N	86	87	58	86	45
Truncated	–	–	30	–	42
Left censored	8 at 0.000	–	–	–	–

Source: Author's model results.
Notes: ***, **, * significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. Hurdle models consist of Probit and Truncated OLS (Trunc OLS). CLAD = censored least absolute deviations regression.

contracts between wineries and their customers. Notably, quality motivations for contract procurement and in-house production of grapes extend to downstream contract use by the grape handlers in our sample, several of which are wineries.

At upstream stages of the supply chain, our results corroborate prior findings that quality considerations and the need to protect investments in specialized or durable assets that support winegrape production significantly increase the use of more formal coordination mechanisms (i.e., formal contracts and vertical integration or ownership of successive stages of the supply chain). Consistent with findings for other industries (Reuer and Arino, 2007), such investments are safeguarded by more complex contracts, with a higher number of contract provisions or terms, including enforcement (i.e., dispute resolution and renewal) provisions, while trade partners' prior experience with each other builds familiarity and trust, decreasing the need for such contract complexity. These points on contract provisions have not been documented previously for the wine industry. As much of the variation in contract provisions was unexplained by our models, there are opportunities for enhancing our understanding of the factors that influence their use. Future research should examine whether these findings hold in other grape and wine production regions, for instance, in U.S. regions with expanding winery tourism.

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