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THE EXTENT AND NATURE OF CONTRACTING IN THE WINE SUPPLY-CHAIN WHEN MORAL HAZARD IS PRESENT

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The extent and nature of contracting in the wine supply-chain when moral hazard is present[1]

Abstract

This paper explores an optimal sharing contract between a grape grower and a winery, when a risk-averse grower allocates efforts among multiple activities that differ in measurability, while double-sided moral hazard is assumed to be present. The contract allows for asymmetric quality contributions by the grape grower and the winery, and is conditioned on both the value of joint production outcomes as well as on the performance evaluation from monitoring. The model is motivated by the use of residual claimancy in the wine industry. Through comparative static analysis of the Pareto optimal share, the model provides insights into the extent and nature of contracting in the wine industries of Australia, New Zealand, California and Spain.

Keywords: incentive contract, residual claimancy, wine, double-moral hazard, multi-tasking

JEL classification: L22, M31, D23

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The choice of appropriate performance indicators is one of the central problems organizations face in implementing effective incentive contracts. It is often difficult to observe and measure actions of agents *per se*, but, as agency theory has long established, it is particularly critical for a principal to find performance indicators such that the agent's actions are aligned with the principal's objectives. The alignment problem can be amplified when agents perform multiple tasks (Holmström and Milgrom 1991). Frequently agents not only need to determine the intensity of their efforts, but also need to allocate their efforts among multiple activities: agricultural producers need to allocate their efforts across a variety of tasks that may differ in their impact on the final good's quality.

When agents perform multiple tasks, issues of internal organizational design may arise for a variety of reasons. First, due to effort substitution, and hence the technological relationship between efforts, second due to direct conflicts between tasks such that their separation is required, and third due to the absence of explicit incentive schemes (Holmström 1999). The multi-tasking literature has established that under these conditions, the performance measures which the principal relies on, may not align the agent with the principal's objectives. In such instances the optimal contract offers weaker overall incentives to ensure that the principal's objectives and the performance indicators remain as closely aligned as possible (Holmström and Milgrom 1991).

This paper focuses on an outcome-based sharing incentive contract in the wine industry where residual claimancy is used to align principal and agent, and where both agent (grape grower) and principal (winery) are assumed to perform multiple tasks. It is assumed that a grape grower contributes to final wine quality in terms of production efforts, and the winery contributes in terms of processing and marketing efforts. Since efforts are mutually imperfectly observed and their impact on final bottle quality can only be imperfectly measured, there is scope for opportunism on both sides.

The objectives of the paper are to derive comparative static results for the optimal sharing rule in a model when contractibility, the grower's risk aversion and the grower's disutility of effort vary, in the presence of double-sided moral hazard and multitasking on both the grower's and the winery's part.

Our model has several desirable features. It allows for asymmetric quality contributions by principal and agent. This is desirable in the context of the wine industry, since winemakers may have a different scope to impact final bottle quality in terms of making 'bad' wine out of 'good' grapes, compared to the grower's scope of affecting the winery's processing efforts. Monitoring is allowed for and rationalized on several accounts. First, theory suggests that outcome-conditioning is not used in isolation, but in combination with input-monitoring, as long as monitoring is informative (Holmström 1979). Thus, varying monitoring intensity can be explained through the sufficient statistic result (Hart and Holmström 1987).[1] Second, a single grower may supply multiple grape varieties, or multiple growers may supply their grapes to a single winery creating scope for free-riding.[2] Third, both parties may be reluctant to condition the sharing rule only on the market valuation of the final bottle, since market risk and other exogenous factors make it desirable to construct a performance measure that is more closely tied to both the individual grower's and winery's contributions.

The model accounts for monitoring assessment grades as part of the compensation scheme. We assume that monitoring activity delivers reports (grades) which then enter the performance indicator. This is a desirable model feature since setting intense incentives and measuring performance carefully can be Edgeworth complements (Milgrom and Roberts 1995), and because we observe that the amount of monitoring of grape growers and the intensity of incentives are chosen together in grape supply contracts (Fraser (2005); Boyd, Evans, and Quigley (2000)).[3]

Our model provides also scope for moral hazard at the level of the winery, where opportunism can emerge when grape growers are dependent on the marketing and quality assessment of the winery. As Fraser (2003) suggests, wineries have incentives to underestimate grape quality, since this lowers the price they have to pay to supplying growers.[4]

Several other aspects differentiate the model in this paper from previous analyses of double-moral hazard and multi-tasking. As in Holmström and Milgrom (1991), we show that the desirability of providing incentives for any one activity decreases with the difficulty of measuring performance in any other activity that makes competing demands on an agent's effort. But whereas Holmström and Milgrom (1991) allow for a risk-averse agent in the presence of hidden action of agents only, this paper considers double-sided moral hazard and introduces sharing contracts to provide joint incentives. The two latter assumptions are also explored in Bhattacharyya and Lafontaine (1995) and Brickley (2002). However, Bhattacharyya and Lafontaine (1995) explore the nature of share contracts in franchising in the absence of multi-tasking, input monitoring and a risk-averse agent. Although Brickley (2002) allows for risk averse agents, the paper considers neither multitasking nor monitoring. In contrast to the two previous papers, our model includes input-conditioning through effort monitoring and assumes multitasking and a risk-averse agent. Our model specifications also permit us to explore strict sharing in double-moral hazard settings when agents are risk-averse.

Through comparative static analysis of the Pareto optimal share, the model provides insights into explicit incentive contracts employed in the wine sector. The model shows that with increasing magnitude of the grower's disutility of effort, a decreasing Pareto optimal share goes to the grape grower. It demonstrates that greater uncertainty of measuring performance results in a smaller Pareto optimal share that goes to the grape grower. As the grape grower's risk aversion goes to infinity, the model predicts that the grape grower's share goes to zero. If there are observation errors in measuring grape grower and winery efforts, and if the grape grower is risk averse, it is shown that the Pareto optimal rate lies strictly between zero and one.

The paper is closely related to the theoretical multi-tasking literature, which has explored distortions of efforts in response to measurement bias when measurability differs between multiple tasks (Holmström and Milgrom (1991); Holmström and Milgrom (1994)), or distortions of efforts that may stem from imperfect proxies for the relationship between the marginal products of the agent's actions and the marginal products of the performance measure (Baker 1992).[5]

There are several multi-tasking studies with empirical applications to which this paper is related. Slade (1996) explores how interrelationships among tasks that operators of gasoline-service stations provide affect the choice of compensation contracts. Luporini and Parigi (1996) study Italian sharecropping contracts over subsistence and cash crops in order to explain the phenomenon of the reintroduction of feudal clauses in sharecropping contracts in the second half of the nineteenth century. Based on grape production data from Renaissance Italy, Ackerberg and Botticini (2002) find empirical evidence of multitasking effects in wine production as determinants of contract type and contract length in the context of a multi-annual optimization problem of grape growers.

Share contracts have perhaps been explored most prominently in the sharecropping literature (e.g. Eswaran and Kotwal (1985)), and in the context of franchising (e.g. Dana and Spier (2001)). Sharing contracts have been motivated in several ways. Stiglitz (1974) has focused on *pure risk sharing* to motivate sharing arrangements when both agent and principal are risk averse and benefit from insurance through sharecropping. Given unverifiable input use, *one-sided moral hazard* has frequently been put forward to rationalize share contracts. Stiglitz (1974), and Mathewson and Winter (1985) in the franchising context, suggest that the trade-off between the provision of insurance and the provision of incentives rationalizes sharing contracts as second-best when agents are risk-averse. Standard agency models based on the first-order approach predict zero sharing (royalty) rates when agents are assumed risk-neutral, when there is hidden action on the agent's part, and when a non-binding wealth constraint is assumed. But when agents are risk-averse (Holmström 1979) or when *double-sided moral hazard* is assumed, royalty rates are predicted to be positive and a sharing contract can be an appropriate second-best contract in addressing underlying double moral hazard problems (Bhattacharyya and Lafontaine (1995); Stiglitz (1974)).

Double-sided moral hazard as an explanation for sharing contracts has a long history in the economics of sharecropping (Stiglitz (1974); Eswaran and Kotwal (1985)). Eswaran and Kotwal (1985) explore market imperfections in inputs and put forward the hypothesis that non-tradable, non-contractible inputs can be efficiently pooled in sharecropping arrangements. But double moral hazard has also been put forward to explain revenue sharing in the context of franchising and supply chain contracts. Lal (1990) explores the implications of an agent's inability to observe the efforts of the principal (franchisor) when brand name investment matters. Rubin (1978) and Bhattacharyya and Lafontaine (1995) have shown that under the assumption that both agent and principal are risk neutral, the optimal contract involves revenue sharing due to the presence of double-moral hazard.[6] Brickley (2002) provides empirical support for the double moral hazard explanation for share contracts in a study on the impact of state franchise termination laws on franchise contracts. In the context of supply-chain contracts and within a double-moral hazard setting, Corbett, DeCroix, and Ha (2001) show that the principal (the supplier) can always induce the optimal second-best equilibrium with a linear shared-savings contract over input use.[7]

The remainder of the paper is structured as follows. Section (2) provides some background to the wine industry. Section (3) develops a sharing contract under the assumption of multitasking, double-moral hazard and effort monitoring. Section (4) concludes.

Background: contractual use in the wine industry

Formal wine grape supply contracts are used extensively in many key wine producing regions, including Australia (Fraser 2005), California (Goodhue, Heien, Lee, and Sumner (2004); Goodhue, Heien, Lee, and Sumner (2002); Bedwell (2000); Moulton (1988)), Argentina (Fares, Ayouz, and Martin 2002); Brazil (Zylbersztajn and Miele (2002)), New Zealand (Boyd, Evans, and Quigley 2000), France (Montaigne and Sidlovits 2003) and Spain (Olmos 2008). As a result of producer surveys, the use of contracts has perhaps been best documented in the case of California (Goodhue, Heien, Lee, and Sumner 2004) and Australia (Fraser 2005).[8]

Industry structure

The wine industry in some of these key producing regions has expanded significantly over the past two decades, resulting in changes in market structure. In Australia, the number of growers has increased by more than 30 per cent to 4,822 between 1994 and 1998. At the same time, the number of wineries expanded by nearly 50 per cent to 1,197 establishments (Shepherd and O'Donell 2001). By 2005, the industry had expanded to approximately 6,000 grape growers and 2,000 wineries (RMN (2007); AWBC (2007)). In California, there were 2,275 wineries and 4,600 grape growers in 2005 (Wine Institute 2007b); compared to 750 wineries and about 5,600 growers in 1987 (Wine Institute 2007a, Moulton (1988)). Thus, since vineyards had also expanded considerably (1988: 297,000 acres; 2005: 445,141 acres; The Wineinstitute 2007), the growers' average vineyard size has increased significantly (by 73%). At the same time, wine production has become more consolidated over time in both regions. In 1987 the 3 largest wineries accounted for 59.2% of California wine shipments (Moulton 1988), whereas the top three wineries were responsible for over 60% of wine shipments in 2003 (Heien and Martin 2003). In Australia, the four largest wineries accounted for 66% of production in 2004 (Aylward 2004), whereas in 1995, seven companies accounted for about 75% of Australia's wine production (Scales, Croser, and Freebairn 1995).

These figures raise the question of whether the bargaining power between grape growers and wineries is typically evenly or unevenly distributed when grape contracts are settled.[9] Evidence from California, New Zealand and Chile suggests that bargaining power is not only a function of scale (on both the grower's and winery's side), but also a function of perceived quality, as greater grower bargaining power was found in high quality grape regions (Moulton (1988); Gwynne (2006)).[10] Davis and Ahmadi-Esfahani (2006) suggest that a recent grape excess supply in Australia may also have been caused by lucrative grape contracts, which implies that wineries have not consistently extracted rents at the expense of growers. Evidence from an Australian study (Scales, Croser, and Freebairn 1995) suggests that the bargaining power of wineries, although generally of concern to growers, has at times shifted toward growers.[11] Scales, Croser, and Freebairn (1995) report that grape growers' bargaining power was found to have strengthened during times of growing export opportunities for wine, and when alternative markets expanded for grapes (i.e. markets for dried vine fruits). Other documented evidence on the extent of bargaining power differences and their price or contracting implications are scarce. A study of the New York State wine industry used a small survey among wineries to econometrically explore the relationship between grape prices and prices of wine (Hefetz and White 1999). The study concludes that "*The clear and significant relations between retail prices and grape prices result from the sharing of revenue from wine sales between the grape growers and the wine* *makers.*" (p.16). Thus, the study provides an example where equality in contract implementation between growers and wineries seems to have occurred.

Type of contract and contractual provisions

Surveys in the main grape growing regions of Australia and California found that 85% (2001) and 72% (1999), respectively, of growers have written contracts (Fraser (2005); Goodhue, Heien, and Lee (1999)). These contracts are typically written over the supply of bulk wine, over grape must or over fresh grapes. In California, fresh grape contracts between grape growers and wine processors are most frequently used (Goodhue, Heien, and Lee 1999). From Fraser (2005) and Boyd, Evans, and Quigley (2000) we have evidence that these contracts have typically a relatively low degree of contract customization, which supports our modeling assumption of simple, uniform linear compensation schemes.

Typical contract provisions include specific production practice (viticultural management) provisions, price incentives (bonuses/penalities for quality attributes of fresh grapes), and monitoring provisions (Olmos (2008); Fraser (2005); Benavente (2004); Goodhue, Heien, Lee, and Sumner (2002); Boyd, Evans, and Quigley (2000); Moulton (1988)), or a subset thereof. The use and documentation of chemical pesticides in grape production is receiving increasing attention, as evidence from Spain, Australia and California suggests (Olmos (2008); Fraser (2005); Goodhue, Heien, and Lee (1999), respectively). A study from Hungary suggests that contracts are offered on a take-it-or-leave-it basis (Sidlovits and Kator 2008), which supports one of our basic model assumptions.[12]

Notably, we have no evidence that grape supply contracts control for exogenous climate variables (rainfall, temperature), although this could be expected from Holmström (1979), as well as from previous empirical studies (Ashenfelter, Ashmore, and Lalonde

(1995); Byron and Ashenfelter (1995)). Ashenfelter, Ashmore, and Lalonde (1995) and Byron and Ashenfelter (1995) have shown that these climate variables can have a significant impact on price and wine quality.

Grape grower monitoring, in the form of winery fieldmen who monitor grower vineyards throughout the growing season, is used extensively by the wineries (Olmos (2008); Fraser (2005); Zylbersztajn and Miele (2005); Goodhue, Heien, Lee, and Sumner (2002); Boyd, Evans, and Quigley (2000)).[13] Such monitoring effort can take many forms, including simple non-binding production advice as well as a strict grading of visible performance indicators that is used as part of the compensation scheme. As a result of such monitoring efforts, wineries have been observed to generate historical performance scorecards for individual growers, which are then used when new contracts are put into place.[14] However, we have also evidence for winery monitoring, such that growers infer winery processing and marketing efforts from trade publications, winery reports and other industry participants. Wineries also submit reports to growers about the composition of their grape juice, or about results from wine tastings (Omond (2003); Montaigne and Sidlovits (2003)). Benavente (2004) emphasizes that "*sharing information within the industry is the norm today - mainly between oenologists and grape growers. This allows the industry to be updated on the quality of wines, procedures and technologies applied by different wineries. This is happening not only in Chile but worldwide ... .*" (p.16).

Evidence from New Zealand suggests that mixed payment schedules composed of a base price and an incentive-related margin are common, where the grower compensation for a particular grape variety is related to the price of wine produced from that particular grape variety (Boyd, Evans, and Quigley 2000).[15]

Grapegrower contracts that condition grower compensation on wine retail prices is a form of residual claimancy that is documented for Australia, France, New Zealand and California (Fraser (2002); Montaigne and Sidlovits (2003); Boyd, Evans, and Quigley (2000); Moulton (1988)). Australian evidence suggests that about 20 percent of grape contracts use residual claimancy with reference to wine retail prices (Fraser 2002). Current figures for bottle price contracts in California are not available, although this figure has been estimated to be under 5 percent during the 1980's (Moulton 1988). Exact figures for France and New Zealand are also not available (Montaigne and Sidlovits (2003); Boyd, Evans, and Quigley (2000)). Documented evidence for the use of residual claimancy in other regions is missing.

For those regions in which residual claimancy is used, bottle retail prices enter the compensation scheme in different ways. In the U.S. and New Zealand, retail bottle prices are used from wines that originated from the same vineyard or the same grape variety, yet from wines that were released in the previous year (Moulton (1988); Boyd, Evans, and Quigley (2000)). In Australia, grape growers are compensated based on retail prices of the forthcoming bottles from the current vintage (Fraser 2005). In France, an average retail price is used to derive an index formula, based on forthcoming bottles from the current vintage, as well as from past vintages (from the same vineyard or grape variety) (Montaigne and Sidlovits 2003). In sum, we observe a variety of ways through which residual claimancy is implemented in the wine industry.

Model

The following model assumes a one-shot game, in which a risk averse grape grower contracts with a risk-neutral winery over the supply of fresh grapes. In addition to modeling multiple tasks on the grower's *and* the winery's side, we allow for moral hazard on both the grower's and the winery's part. Two factors are assumed to contribute to the performance indicator according to which both winery and grower agree to share the outcome from production, processing and marketing. First, the market valuation of the outcome from grape production and wine processing, thus reflecting residual claimancy. Second, information from effort monitoring is also assumed to enter the performance indicator.

The model shows that a sharing contract can provide incentives to both principal (winery) and agent (grower) such that the efficient contract maximizes surplus for all incentive compatible contracts.[16] We consider an agency relationship in which a grape grower allocates his total production efforts amongst several activities $n = 1, ..., N$, where the vector of efforts is denoted by $\boldsymbol{a} = (a_1, ..., a_N)$. The winery allocates its processing and marketing efforts amongst activities $m = 1, ..., M$, where the vector of efforts is given by $\boldsymbol{e} = (e_1, ..., e_M)$ and $\mathbf{a} \in \mathbb{R}_+^N$, $\mathbf{e} \in \mathbb{R}_+^M$, respectively. For both grower and winery, each element of his effort vector measures managerial effort in a distinct activity (variable inputs), such that $\boldsymbol{w} = \begin{bmatrix} \boldsymbol{a}^T & \boldsymbol{e}^T \end{bmatrix}$. Assume that efforts are observed with noise,

$$\tilde{\boldsymbol{w}} = \begin{bmatrix} \boldsymbol{a} \\ \boldsymbol{e} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_{a,w} \\ \boldsymbol{\varepsilon}_{e,w} \end{bmatrix}, \quad \text{such that} \quad \tilde{\boldsymbol{w}} = \begin{bmatrix} \tilde{\boldsymbol{a}} \\ \tilde{\boldsymbol{e}} \end{bmatrix}. \tag{1}$$

We assume the presence of observational error in measuring quality outcomes, such that the realization of $\boldsymbol{\varepsilon}_w = \begin{bmatrix} \boldsymbol{\varepsilon}_{a,w}^T & \boldsymbol{\varepsilon}_{e,w}^T \end{bmatrix}$ is unobserved by both parties; the degree of the winery's inference problem with regards to the grower efforts $\boldsymbol{a}$ is given by the variance of $\boldsymbol{\varepsilon}_{a,w}$, and the degree of the grower's inference problem with regards to the winery efforts $\boldsymbol{e}$ is given by the variance of $\boldsymbol{\varepsilon}_{e,w}$ (mean zero and covariance matrix $\boldsymbol{\Sigma}_w$, $\boldsymbol{\varepsilon} \sim N(0, \boldsymbol{\Sigma}_w)$). An example for the former case could be the difficulty of the winery to observe the actual pesticide applications employed by the grower after signing the contract, which may deviate from the contractually specified pesticide applications.

Symmetrically, the grower may observe the marketing campaign of the winery in the marketplace, but the actual marketing budget that was allocated to specific wines (and the corresponding grape batches from a given grower) may be difficult to observe by the grower.

Further, we allow for a second source of randomness. We assume that both the winery and the grower are exposed to exogenous shocks that make it impossible for both sides to perfectly control their contribution to wine and grape quality, respectively: $\boldsymbol{\varepsilon}_k = \begin{bmatrix} \boldsymbol{\varepsilon}_{a,k}^T & \boldsymbol{\varepsilon}_{e,k}^T \end{bmatrix}$, with mean zero and covariance matrix $\boldsymbol{\Sigma}_k$, $\boldsymbol{\varepsilon} \sim N(0, \boldsymbol{\Sigma}_k)$. These shocks provide scope for moral hazard, because although grower and winery cannot affect the states-of-nature per se, they can affect the outcome realized in those states. The inference problem of the winery with regards to the grower's efforts, and the grower's inference problem with regards to the winery's efforts relates therefore to the potential of mitigating or enhancing the wine quality outcome in an unobserved manner in certain states-of-nature.[17]

Considering both sources of randomness, the wine quality outcome from effort allocation becomes,

$$\boldsymbol{q} = \boldsymbol{\Phi}\boldsymbol{w} + \boldsymbol{\Phi}\boldsymbol{\varepsilon}_w + \boldsymbol{\varepsilon}_k, \tag{2}$$

where $\boldsymbol{\Phi}$ denotes a matrix of productivities. It is the objective of both grower and winery to specify a joint performance indicator that relies on this outcome, $\boldsymbol{q}$. To achieve this, we can model the relationship between efforts and quality outcomes more explicitly. This has two advantages. First, it allows us to transform grape quality attributes into monetary values. Second, this enables us to take production, processing and marketing realities into account. We generally observe that a combination of inputs (production, processing, marketing) is responsible in determining a given quality attribute. For example, the residual sugar level of the grapes (Brix) is influenced by irrigation, weeding and pruning. Assuming that $\boldsymbol{\Phi}\tilde{\boldsymbol{w}} = \boldsymbol{y}$ and $\boldsymbol{y} = \begin{bmatrix} \boldsymbol{y}_a^T & \boldsymbol{y}_e^T \end{bmatrix}$, we have

$$\begin{bmatrix} \boldsymbol{\Phi}_{aa}\tilde{\boldsymbol{w}}_a & + & \boldsymbol{\Phi}_{ae}\tilde{\boldsymbol{w}}_e \\ \boldsymbol{\Phi}_{ea}\tilde{\boldsymbol{w}}_a & + & \boldsymbol{\Phi}_{ee}\tilde{\boldsymbol{w}}_e \end{bmatrix} = \begin{bmatrix} \boldsymbol{y}_a \\ \boldsymbol{y}_e \end{bmatrix}. \tag{3}$$

In this way, equation (3) tells us how grower and winery efforts translate into quality attributes of the wine. As an example, consider $\boldsymbol{\Phi}_{aa}\tilde{\boldsymbol{w}}_a$, which tells us how a grower's effort affects quality attributes that he delivers to the final product. Also, $\boldsymbol{\Phi}_{ea}\tilde{\boldsymbol{w}}_a$ reveals that it is not necessarily the case that the way in which grower efforts affect the winery's quality contribution is symmetric to the way by which winery efforts affect the grower's quality contributions. The extent to which wineries can affect the final bottle quality by making 'bad' wine out of 'good' grapes may differ from the extent to which grape growers can affect the processing efforts of the winery, and thus final bottle quality.[18]

Further, we assume that a vector $\boldsymbol{z}_a$ denotes grower characteristics that are observable by the winery, including characteristics such as location of vineyard, grape varieties planted or production methods used. Winery characteristics that can be observed by growers are denoted as $\boldsymbol{z}_e$, and are assumed to include the type of processing technology employed (e.g. type of oak barrels), the size of vintage and the brand name. These attributes, denoted by $\boldsymbol{z} = \begin{bmatrix} \boldsymbol{z}_a^T & \boldsymbol{z}_e^T \end{bmatrix}$, are a reflection of the contract terms to which both parties have committed to. They also form the basis for the monetary valuation of wine attributes by consumers and marketers at the retail level, as these attributes are assumed to be visible on the wine bottle or elsewhere in the marketplace.[19]

Not only are winery fieldmen assumed to monitor grape growers, but we also assume that winery monitoring is observed, such that growers infer winery processing and marketing efforts from winery reports, trade publications and other industry participants. The resulting 'monitoring scorecards' (grades) are weighted by a contractually-determined matrix $\boldsymbol{V}$, which reflects the relative importance that a given effort is perceived to have for the final outcome from contracting. Further, we assume that matrix $\boldsymbol{Q}$ converts efforts $\boldsymbol{w}$ into grades, such that each effort that has been monitored receives a single grade (diagonal matrix), or several efforts are used to determine a single grade. Therefore, we assume that $\tilde{\boldsymbol{v}}(\boldsymbol{s})=\boldsymbol{VQw}$, and in order to convert these grades into monetary terms, we assume that $\boldsymbol{z}^T[\boldsymbol{VQw}]$. The total performance indicator of the sharing contract is thus,

$$\mu = \boldsymbol{z}^T[(\boldsymbol{\Phi}(\boldsymbol{w} + \boldsymbol{\varepsilon}_w) + \boldsymbol{\varepsilon}_k) + \boldsymbol{VQw}]. \tag{4}$$

To summarize notation and model structure so far, consider Table 1:

Table 1: **Notation and structure of performance measure**

	(I) OUTPUT INFORMATION
$\boldsymbol{w}$	· effort (variable inputs)
$\tilde{\boldsymbol{w}} = \boldsymbol{w} + \boldsymbol{\varepsilon}_w$	· observable effort (with observational noise), $E(\boldsymbol{\varepsilon}_w) = 0$
$\boldsymbol{q} = \boldsymbol{\Phi}\tilde{\boldsymbol{w}} + \boldsymbol{\varepsilon}_k$	· 'production function' (with external shocks), $E(\boldsymbol{\varepsilon}_k) = 0$
$\boldsymbol{\Phi}$	· productivities
$\boldsymbol{z}$	· contract provisions (e.g. grape variety planted, type of oak barrell)
	(II) SUPERVISION
$\boldsymbol{s} = \boldsymbol{Qw}$	· information outcome of monitoring activity
$\boldsymbol{V}$	· weights on monitored variables
$\boldsymbol{z}^T[\boldsymbol{VQw}]$	· conversion of monitoring grades into Dollars
$\tilde{\boldsymbol{v}}(\boldsymbol{s}) = \boldsymbol{Vs}$	$\Rightarrow$ performance indicator $\mu = \boldsymbol{z}^T[(\boldsymbol{\Phi}(\boldsymbol{w} + \boldsymbol{\varepsilon}_w) + \boldsymbol{\varepsilon}_k) + \boldsymbol{VQw}]$
$\boldsymbol{w}: (N+M) \times 1$	$\boldsymbol{\varepsilon}_w : (N \times 1)$, $\quad \boldsymbol{\varepsilon}_k : (M \times 1)$
$\boldsymbol{q}: (M \times 1)$	$\Rightarrow \boldsymbol{\Phi} : (M \times N)$
$\boldsymbol{v}: (M \times 1)$	$\Rightarrow \boldsymbol{V} : (M \times S)$
$\boldsymbol{s}: (S \times 1)$	$\Rightarrow \boldsymbol{Q} : (S \times N)$

The timeline of the model is as following. When the contract is signed, the winery puts forward a sharing rule to the grower. As part of this sharing rule, both parties agree that certain weights will be placed on the informational outcome from monitoring activities. Given the information from monitoring, we obtain $\tilde{\boldsymbol{v}}(\boldsymbol{s})$. The contract also specifies that grape growers are compensated based on retail prices of the forthcoming bottles from the current vintage. After both grower and winery have committed their efforts, and wine is produced, we observe to which contract terms $\boldsymbol{z}$ they have adhered to. This is a reflection of their production function that transformed efforts with observation noise $\boldsymbol{\varepsilon}_w$, and in the presence of random shocks $\boldsymbol{\varepsilon}_k$. Assuming that these contract provisions $\boldsymbol{z}$ have market value and are ultimately responsible for the price of the bottle of wine, we generate revenue that can be shared through a performance indicator as in (4).

The underlying cost-of-effort function ('disutility') is assumed convex and monotone increasing, since the cost-of-effort matrices $\boldsymbol{K}_1$ and $\boldsymbol{K}_2$ are assumed symmetric positive semidefinite and considered in monetary terms:

Assumption 1. $C_w^{'}(\boldsymbol{w}) > 0, \;\; C_{ww}^{''}(\boldsymbol{w}) \geq 0 \;\; \forall w \in \mathbb{R}^N,$

where $C_w^{'}(\boldsymbol{w}) = \frac{\partial C(\boldsymbol{w})}{\partial \boldsymbol{w}}$ and $C_{ww}^{''} = \frac{\partial^2 C(\boldsymbol{w})}{\partial \boldsymbol{w} \partial \boldsymbol{w}^T}$.

Hence, $C_1(\boldsymbol{a}) = \frac{1}{2}\boldsymbol{a}^T \boldsymbol{K}_1 \boldsymbol{a}$ defines the grower's quadratic cost of effort, and $C_2(\boldsymbol{e}) = \frac{1}{2}\boldsymbol{e}^T \boldsymbol{K}_2 \boldsymbol{e}$ denotes the winery's quadratic cost of effort. Therefore $C(\boldsymbol{w}) = \frac{1}{2}\boldsymbol{w}^T \boldsymbol{K}_3 \boldsymbol{w}$, where

$$\boldsymbol{K}_3 = \begin{bmatrix} \boldsymbol{K}_1 & \boldsymbol{K}_{a,e} \\ \boldsymbol{K}_{a,e}^T & \boldsymbol{K}_2 \end{bmatrix}. \tag{5}$$

Since the cost-of-effort matrices $\boldsymbol{K}_1$ and $\boldsymbol{K}_2$ are assumed symmetric positive semidefinite, we can represent efforts as substitutes in the grower's and winery's cost-of-effort function, respectively. In those cases we assume that if the incentive intensity is increased on one effort, this will cause substitution away from other types of efforts.

Given the outcome from monitoring and the outcome from grape and wine production as in equation (4), we assume that the optimal second-best incentive scheme takes the following linear form,[20]

$$\tilde{l} = \alpha(\boldsymbol{z}^T[(\boldsymbol{\Phi}(\boldsymbol{w} + \boldsymbol{\varepsilon}_w) + \boldsymbol{\varepsilon}_k) + \boldsymbol{V}\boldsymbol{Q}\boldsymbol{w}]) + \beta, \tag{6}$$

where α denotes the *commission rate* on the dollar outcome. The size of α reflects thus how strongly powered the incentives are for the grower such that in a high-powered incentive contract, the agent's total returns will be relatively sensitive to the contracting outcome. If $\alpha = 0$, the grower ceases to be an independent supplier, whereas with $\alpha = 1$, the grower would become a fully residual claimant. The scalar β denotes a fixed *ex ante* base payment upon which grower and winery agree when signing the contract.[21]

We could modify our sharing rule further, such that another parameter is determined *ex ante* to the allocation of grower and winery effort. Instead of leaving the relative weights allocated to production outcome vs. monitoring outcome in the performance indicator unspecified, both parties could agree *ex ante* on a base split that is variable: the quality outcome from production could, for example, be linked with the performance of the Consumer Price Index (CPI), resulting in a flexible sharing rule over λ:

$$E[\mu^\star] = \boldsymbol{z}^T[\lambda\boldsymbol{\Phi} + (1-\lambda)\boldsymbol{V}\boldsymbol{Q}]\boldsymbol{w} = \boldsymbol{z}^T\boldsymbol{M}^\star\boldsymbol{w} \tag{7}$$

Indeed, linking wine bottle contracts to the CPI is practiced in the Australian wine industry (Scales, Croser, and Freebairn (1995), Fraser (2002)). However, since this modification does not change the key results in which we are interested, we will proceed as in (6).

Given equation (6), the winery's problem is to allocate the surplus such that expected profits are maximized, subject to the constraints that the winery and the grower comply with the efforts specified in the contract, and subject to the condition that the reservation utility for the grower is assured. While the resulting contract is assumed to be efficient, it leaves the surplus allocation unspecified since retail prices are unobserved *ex ante*: the winery only chooses α and agrees with the grower on the weights that shall be placed on the monitoring outcome.

Assuming a risk-averse grower, we are interested in the variance of the payment scheme (6), as this serves to derive the risk premium. Further, through the covariance matrix, we can analyze random complementarities between tasks. Random complementarities arise when the random allocation of efforts to one quality task increases the marginal expected benefit of allocating efforts to another task, as a result of a random positive demand shock.[22] From (6) we obtain,

$$\begin{aligned}
\mathrm{Var}(\mu(\boldsymbol{a},\boldsymbol{e},\boldsymbol{z})) &= E(\boldsymbol{z}^T(\boldsymbol{\Phi}\boldsymbol{\varepsilon}_w+\boldsymbol{\varepsilon}_k)(\boldsymbol{\Phi}\boldsymbol{\varepsilon}_w+\boldsymbol{\varepsilon}_k)^T\boldsymbol{z}) && \text{(8a)}\\
&= \boldsymbol{z}^T(\boldsymbol{\Phi}\boldsymbol{\Sigma}_{ww}\boldsymbol{\Phi}^T+\boldsymbol{\Phi}\boldsymbol{\Sigma}_{wz}+\boldsymbol{\Sigma}_{zw}\boldsymbol{\Phi}^T+\boldsymbol{\Sigma}_{zz})\boldsymbol{z}, \quad (\boldsymbol{\Sigma}_{ij}=\boldsymbol{\varepsilon}_i\boldsymbol{\varepsilon}_j^T) && \text{(8b)}\\
&\equiv \boldsymbol{z}\boldsymbol{\Sigma}\boldsymbol{z} && \text{(8c)}
\end{aligned}$$

where

$$\boldsymbol{\Sigma} = \begin{bmatrix} \boldsymbol{\Sigma}_{a,a} & \boldsymbol{\Sigma}_{a,e} \\ \boldsymbol{\Sigma}_{a,e}^T & \boldsymbol{\Sigma}_{e,e} \end{bmatrix}.$$

Given the above sharing rule as in equation (6), the grower profits are given by

$$\Pi_a = \alpha\mu - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} + \beta. \tag{9}$$

From the moment generating function for the multivariate normal, $\boldsymbol{\varepsilon} \sim N(\mathbf{0},\boldsymbol{\Sigma})$, we obtain the $CARA$ expected utility of profits as,

$$E[u(\Pi_a)] = -\exp\{-r(\alpha\mu + \beta - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a}) + \tfrac{1}{2}r^2\alpha^2\boldsymbol{z}^T\boldsymbol{\Sigma}\boldsymbol{z}\}, \tag{10}$$

where r denotes the constant absolute risk aversion coefficient, $r = -U''/U'$, $r > 0$. Noting that,

$$E[\mu] = \boldsymbol{z}^T(\boldsymbol{\Phi} + \boldsymbol{V}\boldsymbol{Q})\boldsymbol{w} \tag{11a}$$

$$\equiv \boldsymbol{z}^T\boldsymbol{M}\boldsymbol{w} = \boldsymbol{z}_a^T\boldsymbol{M}_{aa}\boldsymbol{a} + \boldsymbol{z}_a^T\boldsymbol{M}_{ae}\boldsymbol{e} + \boldsymbol{z}_e^T\boldsymbol{M}_{ea}\boldsymbol{a} + \boldsymbol{z}_e^T\boldsymbol{M}_{ee}\boldsymbol{e}, \tag{11b}$$

it follows that the certainty equivalent for the grower is,

$$CE = \alpha(\boldsymbol{z}^T\boldsymbol{M}\boldsymbol{w}) + \beta - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} - \tfrac{1}{2}r\alpha^2\boldsymbol{z}^T\boldsymbol{\Sigma}\boldsymbol{z}. \tag{12}$$

The certainty equivalent utility is thus given by the expected compensation minus the private cost of efforts minus the risk premium. As long as the certainty equivalent utility satisfies the grower's reservation level, he will accept the contract. However, since we assume that contracting takes place in an environment of randomness in *ex post* observed retail prices, the associated information asymmetries require that incentive compatibility constraints are met. In setting up the incentive compatibility conditions, we assume that the grower chooses his own efforts $\boldsymbol{a}$ such that the winery's expected profits are maximized. This optimization problem of the grower excludes the effort choice of the winery, $\boldsymbol{e}$, but includes the variance-covariances since we assume a $CARA$ model of grower choice:

$$\boldsymbol{a} \in \arg\max\{\alpha(\boldsymbol{z}^T\boldsymbol{M}\boldsymbol{w}) + \beta - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} - \tfrac{1}{2}r\alpha^2\boldsymbol{z}^T\boldsymbol{\Sigma}\boldsymbol{z}\}. \tag{13}$$

The necessary first order conditions for (13) are thus,

$$\alpha(\boldsymbol{z}_a^T\boldsymbol{M}_{aa} + \boldsymbol{z}_e^T\boldsymbol{M}_{ea}) - \boldsymbol{a}^T\boldsymbol{K}_1 \leq \boldsymbol{0}, \tag{14a}$$

$$\boldsymbol{a} \geq \boldsymbol{0}, \tag{14b}$$

$$\boldsymbol{a}\Big[\alpha(\boldsymbol{z}_a^T\boldsymbol{M}_{aa} + \boldsymbol{z}_e^T\boldsymbol{M}_{ea}) - \boldsymbol{a}^T\boldsymbol{K}_1\Big] = \boldsymbol{0}. \tag{14c}$$

Assuming that an interior solution exists, we can solve (14a) as a system of equalities for $\boldsymbol{a}$, such that

$$\hat{\boldsymbol{a}}(\boldsymbol{e}) = \alpha\boldsymbol{K}_1^{-1}(\boldsymbol{M}_{aa}^T\boldsymbol{z}_a + \boldsymbol{M}_{ea}^T\boldsymbol{z}_e). \tag{15}$$

Since equation (15) reveals the level of grower effort that maximizes the grower's certain equivalent income in (12), it gives us the incentive compatibility condition that needs to be satisfied to achieve a feasible contract.

In the following step, we substitute the grower's effort choice function (15) into the grower's certainty equivalent income function (12) to obtain the indirect certainty utility of the grower. Denoting

$$E[\mu] = \delta_a[\mu(\boldsymbol{a})] + \delta_e[\mu(\boldsymbol{e})],$$

we can write the indirect certainty equivalent as,

$$\widehat{CE}(\alpha, \boldsymbol{a}) = \beta + \alpha\delta_a[\mu(\boldsymbol{a})] + \alpha\delta_e[\mu(\boldsymbol{e})] - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} - \tfrac{1}{2}r\mathrm{Var}(\alpha\mu\alpha). \tag{16}$$

Together with the participation constraint,

$$\beta + \alpha\delta_a[\mu(\boldsymbol{a})] + \alpha\delta_e[\mu(\boldsymbol{e})] - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} - \tfrac{1}{2}r\mathrm{Var}(\alpha\mu\alpha) \geq U(\overline{v}), \tag{17}$$

in which $U(\overline{v})$ is the default utility level of the grower and $\overline{v}$ is its certain monetary equivalent. As long as the certainty equivalent utility is greater than the default utility of the grower, the grower's performance incentives are not affected, and β serves only as a redistribution (surplus transfer) between winery and grower without affecting the agent's performance incentives (Holmström and Milgrom 1994).[23] From (17), an inequality constraint is implied on the winery's choice for the fixed base payment β:

$$\beta \geq \overline{v} - \alpha\delta_a[\mu(\boldsymbol{a})] - \alpha\delta_e[\mu(\boldsymbol{e})] + \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} + \tfrac{1}{2}r\mathrm{Var}(\alpha\mu\alpha). \tag{18}$$

Thus, to induce the grower's voluntary participation we impose a participation constraint, which, together with the incentive constraint, is necessary to deliver an *incentive feasible contract.*

For convenience, let $\overline{\boldsymbol{K}}_1 = \begin{bmatrix} \boldsymbol{K}_1^{-1} & 0 \\ 0 & 0 \end{bmatrix}$, $\overline{\boldsymbol{K}}_2 = \begin{bmatrix} 0 & 0 \\ 0 & \boldsymbol{K}_2^{-1} \end{bmatrix}$, such that $\overline{\boldsymbol{K}}_1 + \overline{\boldsymbol{K}}_2 = \boldsymbol{K}_3^{-1}$. Considering the grower's optimal effort level from equation (15),

$$E(\mu(\hat{\boldsymbol{a}})) = \alpha(\boldsymbol{z}_a^T\boldsymbol{M}_{aa}\boldsymbol{K}_1^{-1}\boldsymbol{M}_{aa}^T\boldsymbol{z}_a + \boldsymbol{z}_a^T\boldsymbol{M}_{aa}\boldsymbol{K}_1^{-1}\boldsymbol{M}_{aa}^T\boldsymbol{z}_e \tag{19a}$$

$$+ \boldsymbol{z}_e^T\boldsymbol{M}_{aa}\boldsymbol{K}_1^{-1}\boldsymbol{M}_{aa}^T\boldsymbol{z}_a + \boldsymbol{z}_e^T\boldsymbol{M}_{ea}\boldsymbol{K}_1^{-1}\boldsymbol{M}_{ea}^T\boldsymbol{z}_e) \tag{19b}$$

$$= \alpha\boldsymbol{z}^T\boldsymbol{M}\overline{\boldsymbol{K}}_1\boldsymbol{M}^T\boldsymbol{z}. \tag{19c}$$

Given the winery's profit function as,

$$\Pi = (1-\alpha)\mu - \tfrac{1}{2}\boldsymbol{e}^T\boldsymbol{K}_2\boldsymbol{e} - \beta, \tag{20}$$

the expected profit criterion becomes,

$$E(\Pi_e) = (1-\alpha)E[\mu] - \overline{v} + \alpha\delta_a[\mu(\boldsymbol{a})] + \alpha\delta_e[\mu(\boldsymbol{e})] - \tfrac{1}{2}\boldsymbol{a}^T\boldsymbol{K}_1\boldsymbol{a} - \tfrac{1}{2}r\mathrm{Var}(\alpha\mu\alpha). \tag{21}$$

From (21) we know that the participation constraint is binding since $E(\Pi_e)$ is strictly decreasing in β. Together with a strictly positive reservation utility of the grower $\overline{v}$, we know that grapes and wine are produced.

In order to obtain the winery's unconstrained maximization problem, $\max_{a,e} E(\Pi_e)$, we substitute the right-hand side of (15) for $\boldsymbol{a}$ in (21), and the right-hand side of (18) as equality for β into (21). The optimal level of winery efforts is thus given by,

$$\frac{\partial E\Pi_e}{\partial \boldsymbol{e}} = (1-\alpha+\alpha\delta_e)(\boldsymbol{z}_a^T\boldsymbol{M}_{ae} + \boldsymbol{z}_e^T\boldsymbol{M}_{ee}) - \boldsymbol{e}^T\boldsymbol{K}_2 \tag{22}$$

This yields

$$\widehat{\boldsymbol{e}}(\boldsymbol{a}) = (1-\alpha+\alpha\delta_e)\boldsymbol{K}_2^{-1}(\boldsymbol{M}_{ae}^T\boldsymbol{z}_a + \boldsymbol{M}_{ee}^T\boldsymbol{z}_e). \tag{23}$$

Therefore equation (19c) becomes,

$$E[\mu(\widehat{\boldsymbol{e}})] = (1-\alpha+\alpha\delta_e)\boldsymbol{z}^T\boldsymbol{M}\overline{\boldsymbol{K}}_2\boldsymbol{M}^T\boldsymbol{z}, \tag{24}$$

which yields unconstrained profits of the winery,

$$\begin{aligned}\max_{a,e} E(\widehat{\Pi}_e) = \boldsymbol{z}^T[&(1-\alpha+\alpha\delta_a-\tfrac{1}{2}\alpha)\alpha\overline{\boldsymbol{K}}_1 \\ &+ (1-\alpha+\alpha\delta_e-\tfrac{1}{2}(1-\alpha+\alpha\delta_e))((1-\alpha+\alpha\delta_e)\overline{\boldsymbol{K}}_2)\overline{\boldsymbol{M}}^T \\ &- \tfrac{1}{2}r\alpha^2\boldsymbol{\Sigma}]\boldsymbol{z}\end{aligned} \tag{25}$$

$$\begin{aligned}= \boldsymbol{z}^T[&\boldsymbol{M}\{(-\alpha-\tfrac{3}{2}+\alpha^2\delta_a)\overline{\boldsymbol{K}}_1 \\ &+ \tfrac{1}{2}(1+\alpha^2+\alpha^2\delta_e^2-2\alpha-2\alpha^2\delta_e+2\alpha\delta_e)\overline{\boldsymbol{K}}_2\}\boldsymbol{M}^T - \tfrac{1}{2}r\alpha^2\boldsymbol{\Sigma}]\boldsymbol{z}.\end{aligned} \tag{26}$$

In order to find the optimal level of winery efforts,

$$\frac{\partial E(\widehat{\Pi}_e)}{\partial \alpha} = \boldsymbol{z}^T[\boldsymbol{M}\{(1-3\alpha+2\alpha\delta_a)\overline{\boldsymbol{K}}_1 + (\alpha+\alpha\delta_e^2+1-2\alpha\delta_e+\delta_e)\overline{\boldsymbol{K}}_2\}\boldsymbol{M}^T - r\alpha\boldsymbol{\Sigma}]\boldsymbol{z} = 0 \tag{27}$$

Therefore,

$$\alpha^\star = \frac{1}{1 + r\left(\frac{\boldsymbol{z}^T\boldsymbol{\Sigma}\boldsymbol{z}}{\boldsymbol{z}^T\boldsymbol{M}\overline{\boldsymbol{K}}_1^{-1}\boldsymbol{M}^T\boldsymbol{z}}\right)} \tag{28}$$

Several comparative static results can be obtained by considering the *optimal share parameter* $\alpha^\star$ and by varying our assumptions with regard to the degree of effort contractibility, the grower's risk aversion and the grower's disutility of effort:

Proposition 0.1. *As long as the grower is risk-averse, and observational error in measuring quality and randomness on the supply and demand side is present, the optimal contract involves strict sharing:*

Proof.

$$\text{if } \varepsilon_w, \varepsilon_k, r > 0 \quad \Rightarrow \quad \{\alpha : 0 < \alpha < 1\}$$

Q.E.D.

Proposition 0.1. is consistent with previous evidence of strict sharing (i.e. the optimal contract cannot have $\alpha = 0$ or $\alpha = 1$) in the presence of double-sided moral hazard, when both parties are *risk-neutral* and only a single task is performed (Bhattacharyya and Lafontaine (1995), Collary 1). Proposition 0.1. suggests that, under the above model conditions, strict sharing extends to double-moral hazard settings when agents are risk-averse.

Proposition 0.2. *As the magnitude of the grower's disutility of effort increases, and with increasing weight which is placed on the informational outcome of supervision, the Pareto optimal share which goes to the grower decreases.*

Proof.

$$\text{as } \| \boldsymbol{K}_1 \| \to \infty \quad , \quad \boldsymbol{VQw} \to \infty \quad ; \quad \alpha^\star \to 0$$

Q.E.D.

From Proposition 0.2., we would anticipate that as a grower's disutility of effort increases (for example, by expanding into the production of higher quality grapes), the role of monitoring in the incentive contract increases, and a greater Pareto share goes to the winery.

Evidence from Australia and California suggests that the use of production practice provisions (indirect monitoring) and a high direct monitoring intensity is predominant in high-quality grape regions (Scales, Croser, and Freebairn (1995); Goodhue, Heien, Lee, and Sumner (2004); Fraser (2005)). The more extensive use of production practice provisions in grape supply contracts of high quality regions is likely a reflection of the difficulty of identifying and measuring the key grape characteristics that determine grape and thus wine quality (Scales, Croser, and Freebairn 1995).[24] This suggests that the winery uses these provisions as an indirect monitoring mechanism in an attempt to address the incentive problems created by multitasking, when grower efforts between quality tasks differ in measurability at harvest time.

Further, in those cases where wineries contract with high quality grape growers, we anticipate that these wineries, which are likely facing greater multitasking problems and thus higher processing quality risks, receive a higher Pareto share. This increasing Pareto share could thus be expected to be associated with an increasing internalization of contracting externalities associated with multitasking. We would expect that wineries aim to internalize those externalities of incentive design by backward integrating grape production into their own operation, which is indeed reflected in recent empirical evidence from Australia (Scales, Croser, and Freebairn 1995) and Spain (Olmos 2008).[25]

In particular, we observe that production practices in high quality regions encompass the use of winery and wine-specific grape varieties (Scales, Croser, and Freebairn 1995), such that wineries supply growers with new vines on the condition that they have a right to buy the vintage from those vines for a certain number of years (Boyd, Evans, and Quigley 2000).[26] Thus, we have some evidence that the boundary of the firm shifts towards wineries in cases where multitasking problems are likely to be more significant.

The prediction that a different pattern of asset ownership and monitoring intensity between high and low-quality grape growing regions can be related to the extent of the multitasking problem, could also be contrasted to the analysis of Baker and Hubbard (2002). In Baker and Hubbard's (2002) study of the trucking industry, more and improved monitoring technology leads to more integration of trucking into the principal's boundaries, as more asset ownership of the principal is associated with improved incentives. Considering the asserted differences of asset ownership in grape growing regions of different quality, we would expect that the improved efficiency of the backward integrating winery should be accompanied by a greater Pareto share that goes to the winery. Further, from Baker and Hubbard (2002) we would expect that the prediction of increasing backward integration strengthens in light of greater technological advances which are associated with grower monitoring and grape quality measurement.

Proposition 0.3. *With increasing uncertainty of measuring effort contribution, it becomes more efficient to allocate a greater Pareto optimal share to the less risk-averse party:*

Proof.

$$\text{When } \varepsilon_w, \varepsilon_k >> 0, \qquad r \rightarrow \infty \qquad ; \qquad \alpha^\star \rightarrow 0.$$

Q.E.D.

Considering the uncertainty of measuring bilateral efforts, Proposition 0.3. extends insights of previous single-sided moral hazard multi-tasking studies (Holmström and Milgrom (1991), Holmström and Milgrom (1994)) under the above model conditions. It also extends insights of previous double-sided moral hazard models (Bhattacharyya and Lafontaine 1995) with regard to the prediction of varying degrees of risk aversion, since the model of Bhattacharyya and Lafontaine (1995) abstracts from a risk-averse agent.

Proposition 0.3. is consistent with evidence that more backward integration is observed in high-quality regions (Scales, Croser, and Freebairn (1995); Boyd, Evans, and Quigley (2000)). This is in line with our model prediction, since in those wine producing regions, in which (i) effort allocation inference problems and (ii) quality shocks due to states of nature and related moral hazard issues are most likely to be prevalent (i.e. high quality wine regions where both the likelihood and the magnitude of states of nature and their quality implications is expected to be most significant), it is likely more efficient to allocate the winery a greater Pareto share through backward integration. Furthermore, in those instances ((i) and (ii)), it is also likely more efficient to allocate the winery as the less risk averse party a larger Pareto share, since it can bear these risks more efficiently than the grower.

Conclusions

This paper has explored internal organizational design problems of firms in the wine industry, which can arise from the complexity of aspects of performance and the interrelationship between incentive instruments. It has analyzed an efficient sharing contract under the assumption that sharing relates both to the information from monitoring efforts, as well as to the market valuation of joint production outcomes. The wine industry uses residual claimancy as an instrument through such outcome-based incentive contracts.

In order to explore the agency relationship between a grape grower and a winery over the supply of grapes for wine production, a multi-task model is developed which encompasses revenue sharing and double-sided moral hazard. The model allows for asymmetric quality contributions of the contracting parties, and shows that strict sharing can also be supported in bilateral moral hazard settings when agents are risk-averse. Its comparative static results provide insights into what factors determine the allocation of the Pareto optimal share between the contracting parties. Resulting from the comparative static analysis of the Pareto optimal share, the model sheds some light into empirical evidence on differential contracting use in the wine industries of Australia, New Zealand, California and Spain. Since organizational issues and behavioral assumptions that are accounted for in our model are likely to play a key role also in other industry contexts, the insights derived may be useful when studying other labor, health or innovation contracts.

Our model has made a number of convenient assumptions and has thereby left aside important issues that warrant further analysis. Given the static nature of the model, it ignores *ex post* contract renegotiation and an analysis of its consequences (Tirole 1999). The model implies equality in bargaining power between grape grower and winery in implementing contracts. Although we have provided evidence that potential hold-up due to relation-specific investment appears to be limited, and that overall, the balance of bargaining power is not consistently skewed toward the winery, ongoing industry consolidation at the processor level in increasingly global wine markets could change this in the future. Although the model has taken random complementarities between tasks into account, we have been unable to test for their implications empirically. We would expect that Edgeworth complementarities between contracting provisions, as well as complementarities between asset ownership and contract provisions, could help further to explain the differential use of residual claimancy across regions.

Notes

[1]A major implication of the sufficient statistic result is that the principal-agent relationship creates demand for monitoring when there is uncertainty in production, when the agents are risk-averse or when they have limited endowments (Hart and Holmström 1987). For the one-dimensional effort case, Holmström (1979) has used the sufficient statistic argument to demonstrate the benefits of compensating the agent both on output information as well as on information from direct supervision. When multiple tasks are performed by the agent, Holmström and Milgrom (1991) show that we should observe different degrees of monitoring intensity in agency relationships because of differences in the informativeness of performance measures. As they demonstrate in THEOREM 4, the informativeness of performance measures has important implications for asset ownership: with decreasing variance in the performance measure, we expect that a grower's independent activities will be less curtailed, through monitoring for example, than otherwise.

[2]It is well-established that when free-riding occurs as a function of commingling, monitoring can be an important instrument in remedying moral hazard (Holmström 1982).

[3]As Milgrom and Roberts (1995) have established, setting intense incentives and measuring performance correctly can be Edgeworth complements. When we refer to complementarities between

contract provisions, we could consider a broad set of incentive instruments that growers face: the quality bonues and penalties for meeting specific grape quality characteristics, the incentive intensity as reflected in a bottle-price conditioned grower payment, as well as specific production practice provisions. The complementary nature between such incentive instruments implies that as one instrument is used more intensively, the marginal benefit of using other instruments more intensively increases (Holmström and Milgrom 1994). As Holmström and Milgrom (1994) have shown, it is important to consider the endogeneity, i.e. the explicit complementary relationship between those incentive instruments, in order to explain how contracting externalities can affect asset ownership.

[4]Further, we would expect that moral hazard on the part of the winery emerges when it is responsible for processing and marketing grapes of multiple growers, even in instances where free-riding due to commingling grapes from multiple growers is not a problem: due to contractual incompleteness, and because the winery aims to reduce its overall advertising budget, the winery may favor a particular grower in terms of providing stronger marketing support after the supply contract has been signed.

[5]Although Baker (1992) models only the single-task case explicitly, he suggests that the results of his paper are robust in a multi-task setting (p.602).

[6]Rubin (1978) has also shown that when the principal has a greater potential impact on retail demand due to marketing and branding, revenue sharing arrangements can be more suited to provide appropriate incentives rather than profit sharing.

[7]Since this paper explores double-sided moral hazard in incentive contracts, it is also related to the literature on warranties, corporate governance and share contracts. Cooper and Ross (1985) and Mann and Wissink (1989) analyze product warranty contracts in the presence of two-sided moral hazard. Demski and Sappington (1991) show that bilateral moral hazard problems can be resolved if the contract offered by the principal has an option to require a risk-averse agent to buy out the firm at a pre-negotiated price. Wang and Zhu (2005) analyze optimal revenue sharing between joint-venture partners in a two-period double moral hazard model with incomplete contracting.

[8]In California, which grows more than ninety percent of U.S. wine grapes and which is the fourth largest wine producer in the world, wine is the most important processed agricultural product with a \$51.8 billion impact on the state's economy, and an economic impact of \$125.3 billion on the U.S. economy in 2006 (Wine Institute, 2007c). Similarly, Australia's wine industry is an important

contributor to its economy with $2.39 billion wine sales, advancing Australia to the world's fourth largest exporter (Aylward 2004) and sixth largest wine producer in 2005, after France, Italy, Spain, the US, and Argentina (AWBC 2008).

[9]This question is relevant with regard to the following model in section (**??**), since this model assumes equal bargaining power between principal and agent.

[10]Fairweather, Campbell, and Manhire (1999) provide an extensive discussion of two contrasting positions in the New Zealand wine industry on the issue of tension between contracting grape growers and wineries. Their analysis suggests that there is no evidence for a one-sided, excessive bargaining power.

[11]As in commodity markets, we have ample evidence that the bargaining power rests on the buyer's (winery's) side in periods of excess (grape) supply (Fraser 2005).

[12]"*During price definition there is no real negotiation with wine growers of appelation. The merchants announce their prices and the wine-growers can decide that they would like to sell their products to the merchants or not (Sidlovits and Kator (2008), p.17)*

[13]Olmos (2008) reports that 68% of DOC Rioja wineries visit grower vineyards at least three times per year.

[14]Formal evidence of this is given by Zylbersztajn and Miele (2005).

[15]"*... because quality is not entirely attributable to factors within the grower's control, payment based entirely on observed quality is likely to place too much risk on the grower. Due to this trade-off between incentives and risk sharing, mixed payment schedules composed of a base price and an incentive-related margin are common*" (Boyd, Evans, and Quigley (2000), p.8).

[16]The incentive contract has to provide incentives to both winery and grower, and will be second-best as long as we assume that the budget-balancing constraint is satisfied (see Holmström (1982), and Bhattacharyya and Lafontaine (1995) for proof).

[17]Such a shock that can affect the outcome of the wine-quality-contributing efforts of a given grower could be a certain disease in the vineyards. After harvest, the grower could thus supply grapes of lower quality, blaming the pest. However, the winery may contract with other growers from the

same region, and thus find out that the grower in question could have enhanced certain grape (and thus wine) qualities by additional effort, following the disease incident. Similarly, the winery may be exposed to an external shock on its quality-contributing efforts that could for example originate from an input supplier or from the retailer end. A quality shock due to a defective cork may be an example for the former. Due to extreme weather conditions in a given region (or simply due to a lack of storage care under regular conditions), the wine retailer may affect the wine quality through its storage quality efforts, such that a certain wine quality variation that impedes the winery's marketing efforts may be outside of the control of the winery. A winery may therefore suggest *vis a vis* its grower that it suffered a quality shock that was outside of its control, originating from the retail level. However, if the grower would supply the same grapes to multiple wineries (or use some other monitoring device), he may be able to control to what extent the wine's final quality (and thus market success) at the retail level is due to the winery's processing and/or marketing effort, as well as due to the winery's unobserved efforts that may enhance a given quality shock which originated from the retailer end.

[18]The grower can impact the processing abilities of the winery by affecting the fermentation qualities of the wine. The fermentation process can be impeded by an undesired use of certain pesticides and fertilizer (Wade, Holzapfel, Degaris, Williams, and Keller (2004), Downey, Dokoozlian, and Krstic (2006), Lund and Bohlmann (2006)). Further, the final bottle quality may be impeded by grape grower efforts in terms of credence attributes (Darby and Karni (1973), Emons (1997)), even if the fermentation quality is not affected. Evidence from Australia shows that contracts contain a chemical use clause due to potential chemical residues resulting from chemical applications to the grapes (Fraser 2005).

[19]Following the key contributions by Griliches (1971) and Rosen (1974), a number of hedonic studies have derived implicit prices for wine qualities and labeling attributes ((Oczkowski 1994), Nerlove (1995), Steiner (2004)). Perhaps most intriguing in the context of our model is the study by Golan and Shalit (1993), which derives a producer pricing schedule for Israeli grape growers based on the monetary valuation of wine attributes by California consumers and marketers at the retail level.

[20]There exists no sharing contract that implements first-best under double moral hazard, even with risk-neutral agents. Holmström (1982) has shown that any sharing rule which satisfies the budget balancing constraint cannot achieve first-best outcome in team production.

[21]We could also let β take negative values, which would allow for the possibility that the grower

borrows capital from the winery. For example, in Australia, we observe that wineries desire specific grape varieties from grape growers in the production of certain wines (Scales, Croser, and Freebairn 1995). Thus, the winery could suggest that the grower invests into new vines, where the investment will be reimbursed after grape delivery. However, this is likely to turn into a relation-specific asset with hold-up potential. Alternatively, wineries could provide capital to growers for converting vineyards (negative β). Boyd, Evans, and Quigley (2000) provide an example of this from New Zealand.

[22]In a stochastic environment, the covariation of uncertainty across contract provisions implies that the grower is exposed to greater compensation risk. Given the greater sensitivity of the grower to a given incentive (to reallocate efforts) in this environment, we would expect that incentive contracts are used which are of lower power. Therefore, the optimal share parameter should be decreasing in random complementarities, where risks are correlated across tasks.

Further, we would expect that more intense incentive instruments are observed together with higher grower monitoring intensity in high-quality grape growing regions, in which greater quality uncertainty is observed at harvest. Indeed, evidence from Australia suggests that winery representatives make significantly more visits to growers in higher-quality grape regions (Fraser 2005). From Australia and New Zealand (Fraser (2005); Boyd, Evans, and Quigley (2000)), we have support for the hypothesis of a complementary relationship between the intensity of incentives and the intensity of grower monitoring.

[23]Also, as we will show below, the efficiency of the contract does not depend on the choice of β.

[24]"*The various tests currently available to assess grape quality are able to differentiate between bad grapes and good grapes, but they cannot provide a good measure of quality as is necessary when identifying grapes for premium quality wines.*" (Fraser 2005, p.43).

[25]From the above, it was emphasized that when $\alpha = 0$, the winery has fully backward integrated the grower, whereas when $\alpha = 1$, the grower is fully autonomous and residual claimant.

[26]Although Boyd, Evans, and Quigley (2000) do not document whether this procedure is practiced more in high rather than low-quality regions, we would expect that, given the higher transaction costs and investment uncertainty involved in high-quality regions, the practice that wineries supply growers with new vines is more prevalent in high quality regions.

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