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Wine Futures and Advance Selling Under Quality Uncertainty

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This study examines the use of wine futures (i.e., advance selling of wine before it is bottled) as a form of operational flexibility to mitigate quality rating risk. At the end of a harvest season, the winemaker obtains a certain number of barrels of wine that can be produced for a particular vintage. While the wine is aging in the barrel, expert reviewers taste the wine and create a *barrel score*, indicating the potential quality of the wine and offering clues as to whether, when bottled, it will be superior wine. Based on the barrel score, the wine producer determines (1) the percentage of its wine to be sold as futures and (2) the price of the wine futures. After one more year of aging, the wine is bottled, and the reviewers provide a second review of the wine and assign a *bottle score* that influences the market price of the wine. Our study makes three contributions. First, we develop an analytical model that incorporates uncertain consumer valuations of wine futures and bottled wine and the uncertain bottle rating that is assigned to the wine at the end of the production process. Our analysis provides insights into how the barrel score, consumer preference (through a conditional-value-at-risk perspective) and the winemaker's preference influence the winemaker's allocation and pricing decisions. Our second contribution relates to the impact of consumer heterogeneity on the optimal allocation and pricing decisions. Contrary to common belief that the winemaker may be better off when consumers are more homogeneous, our results demonstrate that the winemaker can achieve a higher level of profitability when the market is filled with consumers that are heterogeneous. Third, we test our findings using data collected from Bordeaux wineries engaging in wine futures. Our empirical analysis demonstrates that (1) barrel scores play a significant role in the two decisions regarding the quantity and price of wine futures, and (2) the wine futures market provides a sizable financial benefit to the winemakers. Our analysis yields recommendations for artisanal and boutique wineries that have limited or no experience selling wine futures.

Keywords: wine futures; advance selling; quality uncertainty; pricing

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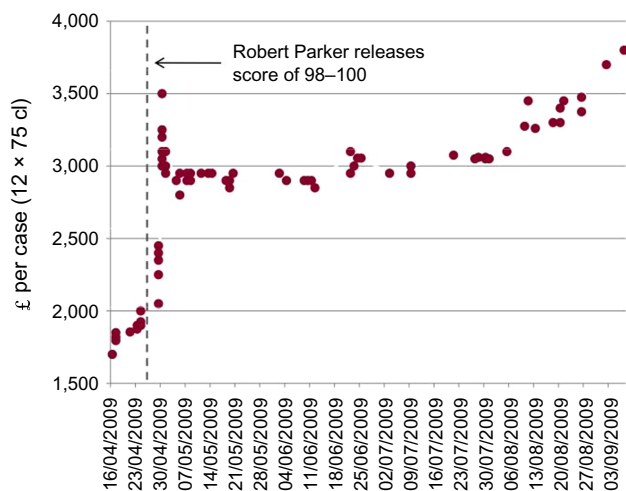
1. Introduction

In this paper we examine the use of wine futures (i.e., advance selling of wine before it is bottled) as a form of operational flexibility to mitigate quality-rating risk associated with the uncertain bottle score. Selling wine while it is still aging in the barrel has been a long practice of “en primeur” (fine wine) producers from the Bordeaux region in France. Since the 17th century, British wine merchants have been purchasing en primeur wine from French producers before the wine completes its aging process. The advance selling of fine wine has become more common in recent times with the establishment of electronic markets. Liv-ex.com is the primary electronic exchange for trading fine wine where merchants, brokers, retailers, and consumers can purchase these wine futures in advance of their distribution for retail

operations. Liv-ex.com has made a profit of £1.4 million on £54.8 million revenues in 2011.

The production process of wine begins at harvest, when the winemaker obtains grapes that vary in quality. After the grapes are sorted, pressed, and fermented, fine wine is aged in barrels for approximately two years before it can be bottled and sold to the general public. During these two years, the winemaker bears the risk of having equity tied up in inventory that almost always fluctuates in value from barrel to final product (i.e., bottled wine). Therefore, in recent times, to reduce the risk of having cash tied up as wine in barrels, many winemakers have begun adopting the traditional French en primeur system, where they set aside a large portion of their total wine production to be sold in advance as wine futures.

We investigate the price and quantity decisions made by the winemaker who obtains two ratings for

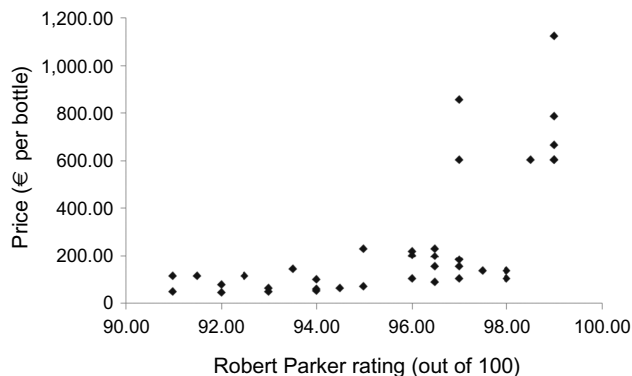
Figure 1 (Color online) Impact of Robert Parker's Barrel Score on the 2008 Lafite Rothschild Futures Price

the wine: first the *barrel score* when the wine is in the early stage of its aging process, and a second *bottle score* when the wine is bottled and is ready to be sold to consumers. At harvest, the winemaker obtains a certain number of barrels of wine. The quality of the wine in the barrels is uncertain because of the varying quality of the grapes that the winemaker obtains each year. After eight to 10 months of barrel aging, outside journalists and independent reviewers are invited to the cellars to taste the wine while it is still in barrels.

The most influential reviewer in the global wine industry is Robert Parker Jr. of the *Wine Advocate*; his reviews are often seen as the industry benchmark. For many Bordeaux wineries, the review by Parker marks the beginning of en primeur campaign for that vintage. An example of Parker's barrel score impact on the futures price of a single wine can be seen in Figure 1. When Parker released his barrel score of 98 to 100 (out of 100) on the 2008 vintage of Château Lafite Rothschild on April 29, 2009, the futures price of the wine increased approximately 75% overnight. Over the next few months, the wine futures price became 50% higher on average than its initial release price. The barrel score that Parker gives to the wine usually determines whether the wine will be a success or a failure.

Barrel scores are typically released at the end of April and in May for participating wineries. At this point, the winemaker decides on the proportion of the total wine production to be sold as futures. Wines with high reviews in the upper 90s are highly sought after by merchants and collectors and can be expected to command high prices. Figure 2 illustrates the effect of Robert Parker's barrel scores on the price of wine futures.

Wine futures allow winemakers to pass on the quality rating risk to consumers and thus gain access to

Figure 2 Influence of Robert Parker's Barrel Scores on the 2010 Bordeaux Wine Futures

cash immediately. However, a negative consequence of selling wine early in the form of futures is that the winery may lose the opportunity of making even higher revenues than what could be obtained from retail sales. An example of this can be seen with one of the well-known Bordeaux "Premier Crus," 1996 Château Lafite Rothschild. In 1997, while this wine was still aging in the barrel, Robert Parker provided a barrel score of 91 to 93, which resulted in an opening price of \$1,400 per case. A year after establishing the barrel score, Parker tasted the wine again and provided a perfect bottle score of 100. As a consequence of this perfect bottle score, the price of the wine rose to \$3,700 per case, resulting in an increase of 150% in price. By selling its wine early in the form of wine futures, Château Lafite Rothschild missed the opportunity of making an even higher profit based on the bottle score.

Although the winemaker may benefit from the increase in the quality of the wine during the aging process, there is also the opposite risk of allocating too much wine for distribution through traditional retail channels. This occurs when the wine does not live up to the expectations, making the price at the end of the aging process lower than that of the futures price, resulting in a loss of future revenues.

Wine futures also exhibit some positive opportunities for consumers, but they come along with risks. First, wine futures enable consumers to gain access to wine that is rare and highly sought after at a cost often lower than the retail price. Second, when consumers purchase wine as futures, they assume the risk of quality-rating uncertainty and may lose out if the wine does not live up to its potential.

Whereas wine futures are commonly used for established wines, the motivation for this study stems from the desire of small and artisanal wine producers to mitigate quality risk. One such winery is Heart & Hands Wine Company in the booming wine region of Finger Lakes in the state of New York. Heart & Hands Wine Company is enjoying national attention

for its outstanding Pinot Noir; the winery won several blind-tasting competitions nationwide, was featured in a CBS morning show, and received a positive review from influential wine critic Eric Asimov of the *New York Times*, along with being featured in a book entitled *Summer in a Glass* by Evan Dawson (2011). The winery now would like to determine what portion of their popular Pinot Noir wine to be sold in advance as wine futures. Our study is targeted to assist the rapid growth of the wine industry in the United States and other regions of the world and help these winemakers mitigate the risk in their revenue cash flows. According to the statistics provided by the Alcohol and Tobacco Tax & Trade Bureau (TTB), the number of wineries in the United States has more than doubled, from 2,688 in 1999 to over 6,000 in 2009. Many of these wineries in the United States are privately owned and operate as family businesses with limited financial resources. Whereas these smaller boutique wineries have been successful in the production of high-quality wines and establishing even a cult status among wine enthusiasts, they have also struggled financially because of high costs and uncertainties that are inherent to wine production.

Our study investigates optimal production allocation for a winemaker that seeks a balance between maximizing the expected profit and reducing the downside risk of a decrease in quality rating. We provide prescriptions for the following research questions:

1. How should a winemaker allocate production between futures and retail distribution in the presence of an uncertain bottle rating?
2. What is the impact of risk aversion and market characteristics on the winemaker's decisions regarding futures quantity and price?
3. How does the value of a futures market for a winemaker depend on the characteristics of the winemaker and the market?

It is important to highlight that the winemaker and buyers of wine futures differ from the traditional description of risk aversion and risk neutrality commonly presented in the industrial organization theory of economics literature. In industrial organization theory, large corporations can diversify their risk; therefore, they do not need to take actions from a risk-averse perspective. According to the same theory, small firms and individual consumers have limited resources such as cash, legal support, etc., and can take actions that exhibit risk aversion. However, we investigate a segment of consumers who are affluent (e.g., collectors) or well diversified (e.g., merchants) and are not typical examples of the consumers as we understand them in industrial organization theory. As will be shown in §5, these consumers exhibit a greater attraction to fine wine and take actions that do not

exhibit significant risk aversion. The winemaker, on the other hand, can exhibit a behavior that is significantly more risk averse. Elevated levels of risk-averse behavior are widely observed among small and artisanal winemakers who have limited financial resources.

This paper is organized as follows. Section 2 reviews the practice of advance selling in economics, marketing, and operations management literature and demonstrates how our work differs from earlier publications. Section 3 examines the relationship between barrel scores, the fraction of wine production sold as futures, and futures prices for Bordeaux wineries. We then present and analyze a model of an individual winemaker's futures allocation and pricing decision in §4. In §5 we use this model in an empirical study of Bordeaux wineries and an artisanal winemaker in the United States. The numerical analysis enables us to highlight the contrasting aspects of the two wine producing regions in France and the United States. Section 6 presents our prescriptions and conclusions.

2. Literature Review

Advance selling is a common marketing practice in which sellers offer buyers the opportunity to purchase goods or services before the time of consumption. Early publications in marketing literature describe advance selling as a tool to price discriminate and manage fluctuations in demand in the airline and leisure industry (Gale and Holmes 1992). Gale and Holmes (1993) illustrate that firms facing demand uncertainty with limited capacity can expand their output by adopting advance selling to induce buyers to purchase early, thereby reducing the demand risk at the time of consumption. This study is similar to Gale and Holmes (1993), because we show that the winemaker can mitigate demand risk by adopting advance selling as a form of allocation flexibility. However, we depart from their study by introducing the uncertainty in bottle scores, which in turn influences both the allocation decision of the winemaker and the consumer valuation of the wine.

Recent publications in marketing literature focus on the conditions in which advance selling becomes beneficial. Shugan and Xie (2000, 2005) and Xie and Shugan (2001) show that the conditions that make advance selling beneficial are far more general than previously thought. These studies conclude that advance selling does not only benefit firms that operate under a capacity constraint but is also an effective marketing tool. Fay and Xie (2010) extend their work by comparing the use of advance selling and probabilistic selling, deriving the conditions under which one dominates the other. Cho and Tang (2013) compare advance selling with regular selling and dynamic selling.

There is an abundance of marketing literature in the area of advance selling, but few have studied the problem from an operations and supply chain management perspective. Su (2007) and Su and Zhang (2008, 2009) examine the situation where firms participate in multiple selling periods over a finite time. Although these studies do not consider the use of advance selling, they shed light on the area of strategic customer behavior, specifically the influence of forward-looking and myopic buyers on the firm's pricing and selling decisions.

In the past there have been many studies in economics and finance (e.g., Kohn 1978) that illustrate the effect of speculators in the resale market. In operations management literature, Su (2010) considers the problem where there are both speculators and genuine buyers in the market, and shows that firms can gain additional benefits by mimicking the actions of the resellers in the resale market when consumer valuations are fixed over time. Our study departs from Su (2010) by allowing for the quality rating to fluctuate between the two selling periods; in turn, our study influences the consumer valuation of the product during the two selling periods. In other words, we allow for exogenous factors to influence consumer valuation before the time of consumption. Tang and Lim (2013) extend the work in this field by examining the interrelationship between speculators and forward-looking consumers. They develop conditions in which sellers can benefit from the existence of speculators in the market. Specifically, they show that when the expected valuation is decreasing over time, speculators can be beneficial in generating future demand. Boyacı and Özer (2010) make use of advance selling (as customers' early commitment to purchase goods) in determining capacity decisions.

In recent times, there has been an emergence of research that considers the use of various operational flexibilities to mitigate demand uncertainty. Van Mieghem and Dada (1999), Petruzzi and Dada (1999), Dana and Petruzzi (2001), Federgruen and Heching (1999, 2002), and Kocabiyıkoğlu and Popescu (2011) show that firms can adopt production and pricing flexibilities to mitigate demand risk under deterministic supply. Furthermore, Van Mieghem and Dada (1999) demonstrate that, under postponed pricing, production postponement has little benefit to the manufacturer. Our essay departs from these studies because it features (1) quality-rating uncertainty, (2) the use of advance selling in addition to pricing flexibility that can be used to mitigate demand risk, and (3) a risk-averse firm that benefits from recuperating income in advance. Moreover, we show that advance pricing and advance allocation may be beneficial to firms that have significant amount of cash tied up in inventory that may diminish in value.

In addition to the pricing flexibility, Jones et al. (2001), Kazaz (2004), and Kazaz and Webster (2011) illustrate that firms can also mitigate demand uncertainty by utilizing a secondary source of supply. Our work differs from these studies because we examine the problem of managing demand uncertainty through the use of advance selling as a secondary market for consumers instead of adopting a secondary source of supply in the production process.

In operations and supply chain management, quality uncertainty is often seen as uncertainty in the production process where multiple products with varying quality are produced simultaneously in a single production run. Bitran and Dasu (1992), Bitran and Gilbert (1994), Nahmias and Moynzadeh (1997), Bassok et al. (1999), Hsu and Bassok (1999), Tomlin and Wang (2008), Öner and Bilgiç (2008), Noparumpa et al. (2015), and Bansal and Transchel (2014) all examine the challenges in coproduction systems and investigate the firm's downward substitution decisions under various settings. However, in this study, we examine quality uncertainty from a different perspective. We investigate a problem where the quality of wine can fluctuate during the course of the aging process; hence, this presents the winemaker with the opportunity to allocate a proportion of the total production to be sold as futures in advance, thereby reducing the risk of the variation in quality in future periods.

In sum, our study integrates two important disciplines, namely marketing and operations management, by studying the use of advance selling from two different perspectives. From a marketing perspective, we show that advance selling can act as a method to price discriminate buyers, enabling the winemaker to extract additional surplus from the consumers. From an operations management perspective, in the presence of quality-rating uncertainty, advance selling allows the winemaker to pass on the risk of holding inventory that fluctuates in value because of quality-rating uncertainty to buyers of wine futures, while recuperating the necessary cash that is required for reinvestment early in the production process.

3. Relationship Between Barrel Scores, Allocation of Wine as Futures, and Futures Prices

This section presents how well barrel scores explain the winemaker's two decisions: the percentage of wine allocated to be sold in the form of wine futures, and the price of these wine futures. We demonstrate this relationship by using data collected from 12 winemakers in the Bordeaux region, six from the Right Bank and six from the Left Bank wine-growing districts: Angelus (Right Bank), Cheval Blanc (Right

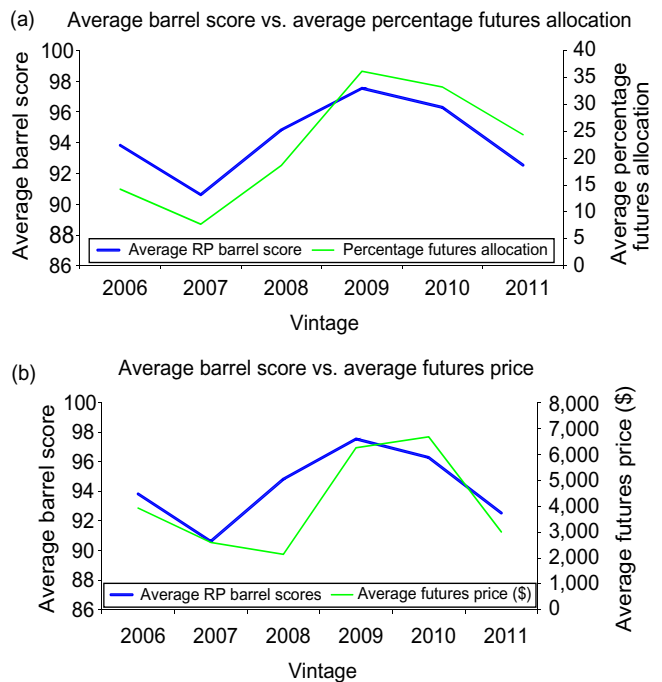
Bank), Clos Fourtet (Right Bank), Cos d'Estournel (Left Bank), Ducru Beaucaillou (Left Bank), Duhart Milon (Left Bank), Evangile (Right Bank), Leoville Poyferre (Left Bank), Mission Haut Brion (Left Bank), Pavie (Right Bank), Pichon Lalande (Left Bank), and Troplong Mondot (Right Bank). The data, which are used in the analysis presented in this section as well as §5, are collected from three sources.

We collected data on futures prices and quantities traded from Liv-ex, the largest source of fine wine data in the world. Vintages from 2006 to 2011 are used in the study. For the 12 wineries included in the study, there were 307,909 cases traded in the form of futures in a total of 32,869 futures transactions. For the barrel and bottle scores, we collected data from the most influential wine critic, Robert Parker Jr., using the *Wine Advocate* and the journal's digital platform <http://www.erobertparker.com>. Production quantities for the wineries during the vintages included in the study were obtained from *Wine Spectator*.

Figure 3 shows the average barrel scores, average futures allocation, and average price for the 12 Bordeaux winemakers for vintages from 2006 through 2011. Panel (a) of Figure 3 presents the impact of average barrel scores on the average percentage of wine allocated for futures, and panel (b) of Figure 3 presents the impact on the average price.

Figure 3 shows a close relationship between each pair of curves. We next quantify these relationships beginning with the percentage of wine allocated as futures. We denote the percentage of wine allocated as futures as α_{jt} and barrel scores as s_{1jt} for winery j and vintage t . For each winery, we express the mean and standard deviations of the percentage of wine sold as futures and barrel scores with $\bar{\alpha}_j$, σ_{α_j} and the mean and standard deviations of barrel scores with \bar{s}_{1j} and $\sigma_{s_{1j}}$, respectively. The normalized values of percentage allocation of wine as futures and barrel scores are $\hat{\alpha}_{jt} = (\alpha_{jt} - \bar{\alpha}_j) / \sigma_{\alpha_j}$ and $\hat{s}_{1jt} = (s_{1jt} - \bar{s}_{1j}) / \sigma_{s_{1j}}$, respectively. We regressed the normalized values of the percentage of wine allocated as futures ($\hat{\alpha}_{jt}$) based on the normalized values of Robert Parker's barrel tasting scores (\hat{s}_{1jt}). Table 1 provides the linear and quadratic regression results in Models 1 and 2, respectively. In

Figure 3 (Color online) Impact of Average Barrel Scores Given by Robert Parker on Bordeaux Winemakers' (a) Average Percentage Allocation of Wine for Sale as Wine Futures and (b) Futures Prices



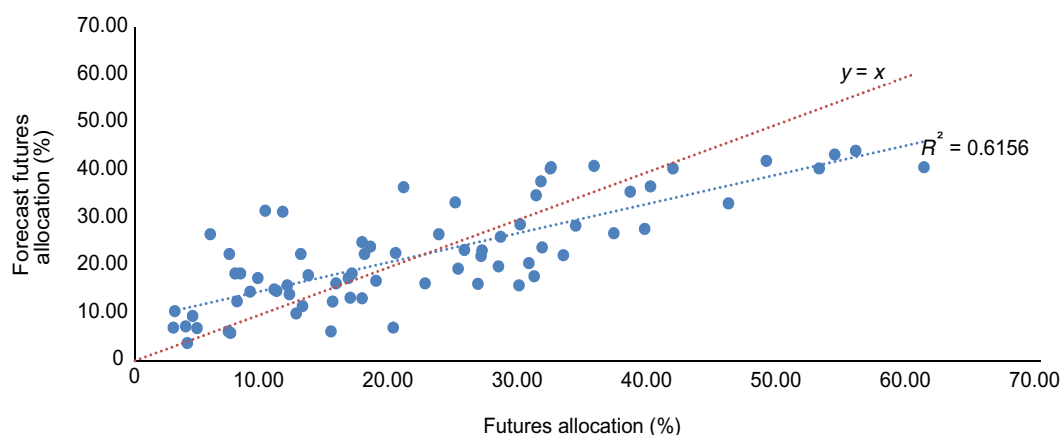
all of our regression analyses, ** and *** imply that the variable is statistically significant at 5% and 1% levels, respectively, based on p -values. Table 1 shows that the barrel score is a statistically significant variable at less than 1% and that the barrel score explains a fairly large portion of the amount of wine that should be allocated as wine futures. In the quadratic regression model, the squared barrel score is not statistically significant, and the adjusted R^2 does not improve significantly; therefore, we use the linear regression model (Model 1 in Table 1) to estimate the percentage of wine that should be allocated for the futures market. Figure 4 shows the fit of this linear regression model using the actual percentage allocation with the predicted allocation percentage.

Table 1 Summary of Linear Regression Results for the Normalized Values of Wine Allocated as Futures vs. the Normalized Values of Barrel Scores

Parameter	Model 1		Model 2	
	Coefficient	(p -value)	Coefficient	(p -value)
Intercept	-2.13×10^{-16}	(1)	-0.100	0.364
Barrel score (\hat{s}_{1jt})	0.709	$(3.17 \times 10^{-12})^{***}$	0.721	$(2.05 \times 10^{-12})^{***}$
Barrel score ² (\hat{s}_{1jt}^2)			0.120	0.205
Adjusted R^2	0.50		0.50	

***Statistically significant at the 1% level.

Figure 4 (Color online) Fit Between the Normalized Actual Futures Allocation and Forecasted Futures Allocation



We denote the futures price for winery j and its vintage t by f_{jt} . Describing the mean and standard deviations of the futures prices for winery j with \bar{f}_j and σ_{f_j} , respectively, the normalized futures price is expressed as $\hat{f}_{jt} = (f_{jt} - \bar{f}_j) / \sigma_{f_j}$. Table 2 shows that the barrel score is a statistically significant variable at less than 1% in both linear and quadratic regression models, Models 1 and 2, respectively. The predictive power and the adjusted R^2 can be increased from 0.50 to 0.54 by using the quadratic regression model where the squared barrel score shows significance at 5%.

In sum, we can conclude that barrel scores explain a fairly large portion of the percentage allocation and futures price decisions. We next build an analytical model that determines the allocation percentage and futures price under bottle score uncertainty for a risk-averse winemaker.

4. Model and Properties

In this section we propose and analyze a model for an individual winery that can help explain this behavior and shed light on our research questions. We consider a winemaker who determines how to allocate its wine between futures and retail sales while facing quality-rating uncertainty. At time t_0 , which corresponds to the end of the harvest season, the winemaker obtains the total number of barrels of wine to

be produced for that vintage, denoted Q . At time t_1 , after eight to 10 months of barrel aging, the winemaker invites experts such as Robert Parker Jr. of the *Wine Advocate*, James Suckling of the *Wine Spectator*, and Eric Asimov of the *New York Times* to taste the wine. This event results in a barrel score for both the winemaker and consumers. At this point the winemaker determines the quantity of wine to be sold as futures, denoted q_f , which in combination with the barrel score, determines the corresponding price of wine futures, denoted p_f . Equivalently, the winemaker's decision can be interpreted as setting the futures price p_f , which in combination with the barrel score determines q_f . The remaining portion of wine that is not allocated for sales as futures, denoted with $q_r (= Q - q_f)$, is reserved for retail sales. At the end of the aging process, at time t_2 , the wine is bottled and sent for blind tasting. At this time the bottle score is revealed, and the wine is sold at a retail price p_r that responds to the bottle rating. Figure 5 illustrates the timeline of events that the winemaker faces during the production process.

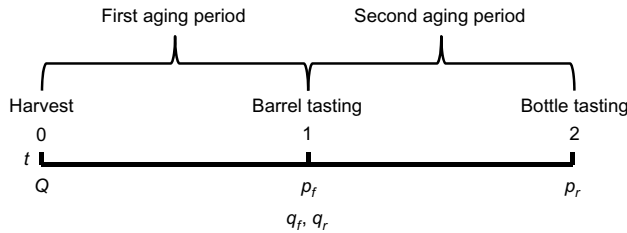
The realized barrel score is denoted s_1 . The random bottle score is \tilde{s}_2 , and its realization is s_2 . The barrel score provides an indication of the final bottle score s_2 . In particular, the expectation of the bottle score at time t_1 when the barrel score is revealed is identical to the barrel score, i.e., $E[\tilde{s}_2 | s_1] = s_1$. The coefficient of

Table 2 Summary of Linear Regression Results for the Normalized Values of Futures Prices vs. the Normalized Values of Barrel Scores

Parameter	Model 1		Model 2	
	Coefficient	(<i>p</i> -value)	Coefficient	(<i>p</i> -value)
Intercept	-2.52×10^{-16}	(1)	-0.197	(0.065)**
Barrel score (\hat{s}_{1jt})	0.071	$(2.03 \times 10^{-12})^{***}$	0.737	$(1.9 \times 10^{-13})^{***}$
Barrel score ² (\hat{s}_{1jt}^2)			0.236	(0.010)**
Adjusted R^2	0.50		0.54	

** and *** statistically significant at the 5% and 1% levels, respectively.

Figure 5 Timeline of Events and the Decisions Made by the Winemaker During the Aging Process



variation of \tilde{s}_2 is denoted c_v , and the variance of \tilde{s}_2 is denoted $\sigma^2 (= V[\tilde{s}_2 | s_1] = (s_1 c_v)^2)$. The random bottle score \tilde{s}_2 is derived from the standardized random variable \tilde{z} that is independent of s_1 and is expressed as $\tilde{s}_2 = s_1 + \tilde{z}\sigma = s_1(1 + \tilde{z}c_v)$; the expected value and variance of \tilde{z} are defined as $E[\tilde{z}] = 0$ and $V[\tilde{z}] = 1$, respectively. The realization of random variable \tilde{z} is z ; the probability density function and the cumulative distribution function of \tilde{z} are $g(z)$ and $G(z)$, respectively.

The retail price of bottled wine is influenced by the bottle score. Without loss of generality, we normalize the bottle price such that the price of retail wine is equivalent to the bottle rating of the wine, i.e., $p_r = p_r(s_2) = s_2$. It follows that the expected retail price at time t_1 is the barrel score, i.e., $E[p_r(\tilde{s}_2 | s_1)] = s_1$.

4.1. Consumers' Valuation of a Wine Future

Each individual in the futures market has idiosyncratic preferences. At time t_1 , consumers in the wine futures market make a choice between three alternatives: purchase a future, purchase at retail, or do not make a purchase. The average valuation of a future at time t_1 among futures consumers, denoted v_f , depends on three factors: (1) the expected bottle score (equal to s_1), (2) the coefficient of variation of bottle score c_v (reflecting quality risk), and (3) the risk-free rate of return r_f . The risk-free rate of return is one factor that influences the time-value-of-money effect caused by paying today and receiving the product in the future.

We next present a model for v_f and use this model to derive a consumer's risk-adjusted discount rate. This model uses a conditional-value-at-risk (CVaR) framework for assessing how the average consumer values a future under bottle-score uncertainty.

For a given $\xi \in (0, 1]$, let $z(\xi) = G^{-1}(\xi)$ describe the ξ th percentile of the bottle score \tilde{s}_2 , i.e., $s_2(\xi) = s_1(1 + z(\xi)c_v)$. The valuation of wine futures by an average consumer is equal to the conditional expected value of the bottle score discounted to time t_1 at the risk-free rate, i.e.,

$$\begin{aligned} v_f &= (1 + r_f)^{-1} E[\tilde{s}_2 | s_1, \tilde{s}_2 \leq s_2(\xi)] \\ &= (1 + r_f)^{-1} s_1 (1 - E[-\tilde{z} | \tilde{z} \leq z(\xi)] c_v) = \theta s_1, \end{aligned}$$

where $\theta = (1 + r_f)^{-1} (1 - \gamma c_v)$ is the risk-adjusted discount factor, and $\gamma = E[-\tilde{z} | \tilde{z} \leq z(\xi)]$ is a measure of sensitivity to uncertainty in the bottle score. Note that γ is decreasing in ξ , $\gamma \geq 0$ (because of $E[\tilde{z}] = 0$), and $\gamma = 0$ when $\xi = 1$. In this model, a consumer is more concerned with the possibility of low realizations of \tilde{s}_2 than high realizations of \tilde{s}_2 and lowers her valuation from the risk-free discounted mean $(1 + r_f)^{-1} s_1$. The degree of reduction depends upon the risk parameter γ and the coefficient of variation of bottle score c_v .

We next derive the random utility of a futures purchase at time t_1 . The valuation of a future by a random consumer is

$$V_f = v_f + \varepsilon_f = \theta s_1 + \varepsilon_f,$$

where ε_f is a random variable with $E[\varepsilon_f] = 0$, and the utility of a future is the consumer surplus—the difference between valuation and price, i.e.,

$$U_f = V_f - p_f = \theta s_1 + \varepsilon_f - p_f.$$

The average utility of a future among consumers is

$$u_f = E[U_f] = \theta s_1 - p_f.$$

We see that the utility of a futures purchase is increasing in the expected bottle score (s_1) and is decreasing in price (p_f), uncertainty in bottle score (c_v), the risk-free discount rate (r_f), and risk aversion (γ).

A consumer who does not purchase a future at time t_1 has two alternatives at time t_2 : (1) purchase a bottle at retail price $p_r(\tilde{s}_2 | s_1) = \tilde{s}_2$, (2) do not purchase. The average utility of a retail purchase choice at time t_1 among consumers is the difference between the expected valuation and the expected price discounted by the risk-adjusted discount rate, i.e.,

$$u_r = \theta (E[\tilde{s}_2 | s_1] - E[p_r(\tilde{s}_2 | s_1)]) = 0,$$

and the random utility is

$$U_r = \varepsilon_r$$

where ε_r is a random variable with $E[\varepsilon_r] = 0$. Similarly, the average utility of the no-purchase option is zero, and the random utility is

$$U_0 = \varepsilon_0.$$

The utility of not purchasing a future at time t_1 is the maximum utility among the two no-purchase alternatives: $\max\{U_r, U_0\} = \max\{\varepsilon_r, \varepsilon_0\}$.

We next derive the futures purchase probability. At time t_1 , a consumer selects the alternative with the highest utility; the fraction of consumers who purchase a future is

$$P[U_f > \max\{U_r, U_0\}] = P[\max\{\varepsilon_r, \varepsilon_0\} - \varepsilon_f < \theta s_1 - p_f].$$

We assume that ε_f , ε_r , and ε_0 are i.i.d. Gumbel random variables with zero mean and scale parameter β . Thus, $\max\{\varepsilon_r, \varepsilon_0\}$ is a Gumbel random variable with $E[\max\{\varepsilon_r, \varepsilon_0\}] = \beta \ln 2$ and scale parameter β (i.e., the Gumbel distribution is closed under maximization), $\max\{\varepsilon_r, \varepsilon_0\} - \varepsilon_f$ is a logistic random variable (i.e., the difference between two independent Gumbel random variables with the same scale parameter is a logistic random variable), and the futures purchase probability conforms to the multinomial logit (MNL) model:

$$P[U_f > \max\{U_r, U_0\}] = \frac{e^{(\theta s_1 - p_f)/\beta}}{2 + e^{(\theta s_1 - p_f)/\beta}}.$$

The MNL model is widely used in practice and is empirically well supported (McFadden 2001, Talluri and van Ryzin 2004, Vulcano et al. 2010). As we will see in §5, Bordeaux winery data provides empirical support for our consumer-choice model.

The market size for wine futures is denoted by $M(s_1)$. The market size is a nondecreasing function of the barrel score s_1 (i.e., $M'(s_1) \geq 0$), and reflects the phenomenon that a higher barrel score creates hype for the wine and increases the market size. Each individual in the futures market selects the alternative with the highest utility. Accordingly, the demand for futures is governed by the MNL model, i.e.,

$$\begin{aligned} q_f(p_f) &= M(s_1)P[U_f > \max\{U_r, U_0\}] \\ &= M(s_1) \left[\frac{e^{(\theta s_1 - p_f)/\beta}}{2 + e^{(\theta s_1 - p_f)/\beta}} \right]. \end{aligned} \quad (1)$$

We can invert (1) to write price as a function of quantity:

$$p_f(q_f) = \theta s_1 + \beta \ln \left[\frac{M(s_1) - q_f}{2q_f} \right]. \quad (2)$$

4.2. The Winemaker's Problem

We denote the winemaker's risk-adjusted discount factor as ϕ . Similar to the consumer's risk-adjusted discount factor, the value of ϕ depends on the risk of selling a bottle of wine at an uncertain retail price in the future. The higher the uncertainty in bottle price and the more risk-averse the winemaker, the lower the value of ϕ .

Based on the above definitions, the winemaker's risk-adjusted expected profit can be expressed as

$$\begin{aligned} \Pi(q_f) &= q_f p_f(q_f) + \phi E[p_r(\tilde{s}_2 | s_1)](Q - q_f) \\ &= q_f \left((\theta - \phi)s_1 + \beta \ln \left[\frac{M(s_1) - q_f}{2q_f} \right] \right) + \phi s_1 Q, \end{aligned} \quad (3)$$

and the winemaker's problem is

$$\rho^* = \max_{q_f \leq Q} \Pi(q_f). \quad (4)$$

4.3. Optimal Decisions and Profit

Aydin and Porteus (2008) consider the problem of maximizing profit with the price-demand function governed by the MNL model. They show that the first-order condition with respect to price yields the optimal price when price is not restricted. Li and Huh (2011) consider the nested MNL model of demand. They show that the profit function is concave in quantity and identify expressions for the optimal quantity, price, and profit. Our profit model exhibits the same structure as the MNL profit function but includes a constraint on quantity. Compared to a classical MNL-based profit function, (3) contains an additional fixed term $\phi s_1 Q$; the term ϕs_1 in (3) is structurally equivalent to the unit cost term in the profit function.

The following proposition draws on these earlier results to specify expressions for ρ^* , the optimal futures quantity q_f^* , and the optimal futures price p_f^* . These expressions rely on the Lambert W function $W(z)$ (Corless et al. 1996); $W(z)$ is the value of w satisfying $z = we^w$.

PROPOSITION 1. Let $\alpha^0 = e^{(\theta - \phi)s_1/\beta - W(e^{(\theta - \phi)s_1/\beta}/2e)} / (2e + e^{(\theta - \phi)s_1/\beta - W(e^{(\theta - \phi)s_1/\beta}/2e)})$. If $\alpha^0 \leq Q/M(s_1)$, then

$$q_f^* = M(s_1) \left(\frac{e^{(\theta - \phi)s_1/\beta - W(e^{(\theta - \phi)s_1/\beta}/2e)}}{2e + e^{(\theta - \phi)s_1/\beta - W(e^{(\theta - \phi)s_1/\beta}/2e)}} \right), \quad (5)$$

$$p_f^* = \phi s_1 + \beta \left[1 + W \left(\frac{e^{(\theta - \phi)s_1/\beta}}{2e} \right) \right], \quad (6)$$

$$\rho^* = M(s_1) \left[\beta W \left(\frac{e^{(\theta - \phi)s_1/\beta}}{2e} \right) + \phi s_1 \frac{Q}{M(s_1)} \right]; \quad (7)$$

otherwise,

$$q_f^* = Q, \quad (8)$$

$$p_f^* = \theta s_1 + \beta \ln \left[\frac{M(s_1) - Q}{2Q} \right], \quad (9)$$

$$\rho^* = Q \left(\theta s_1 + \beta \ln \left[\frac{M(s_1) - Q}{2Q} \right] \right). \quad (10)$$

The value of α^0 in Proposition 1 is the optimal fraction of the futures market that purchases futures when the supply constraint is nonbinding. Expressions (8)–(10) apply when the available supply as a percent of the market size is smaller than this fraction.

4.4. The Impact of Parameters:

Comparative Statics

We next present a proposition that shows the impact of changes in parameter values on optimal values. Let α^* denote the optimal fraction of the futures market that purchases futures. From Proposition 1, it follows that

$$\alpha^* = \min \left\{ \alpha^0, \frac{Q}{M(s_1)} \right\}.$$

Table 3 Impact of an Increase in Parameter Values on Optimal Values

Condition	Increase	Supply constraint is not binding				Supply constraint is binding			
		α^*	q_f^*	p_f^*	ρ^*	α^*	q_f^*	p_f^*	ρ^*
$\theta = \phi$ $\theta = \phi$ $\theta > \phi$ $\theta > \phi$ $\theta < \phi$ $\theta < \phi$	c_v	↓	↓	↓	↓	—	—	↓	↓
	γ	↓	↓	↓	↓	—	—	↓	↓
	$\theta - \phi$	↑	↑	↓ or ↑	↓ or ↑	—	—	↓ or ↑	↓ or ↑
	θ	↑	↑	↑	↑	—	—	↑	↑
	ϕ	↓	↓	↓ or ↑	↓ or ↑	—	—	—	—
	Q	—	—	—	—	↑	↑	↓	↑
	s_1	—	↑ ¹	↑	↑	↓	—	↑	↑
	β	—	—	↑	↑	—	—	↓ or ↑	↓ or ↑
	s_1	↑	↑	↑	↑	↓	—	↑	↑
	β	↓	↓	↓ or ↑	↓ or ↑	—	—	↓ or ↑	↓ or ↑
$\theta < \phi$ $\theta < \phi$	s_1	↓	↓ or ↑ ²	↓ or ↑ ³	↓ or ↑	↓	—	↓ or ↑	↓ or ↑
	β	↑	↑	↑	↑	—	—	↓ or ↑	↓ or ↑

Key. ↑ = increase; ↓ = decrease; ↓_↑ = decrease, then increase; — = no change; ↓ or ↑ = both possible. When $M(s_1) = M$ for all s_1 , then ¹—, ²↓, ³↑.

PROPOSITION 2. The results in Table 3 show the impact of an increase in a parameter on optimal values.

Proposition 2 provides insight regarding the impact of various consumer and market factors on the winemaker's utilization of the wine futures market. We next discuss individually the influence of select factors.

4.4.1. The Impact of Consumers' and Wine-maker's Risk Preferences. Proposition 2 shows that higher bottle score uncertainty (c_v) and risk aversion (γ) cause the winemaker to reduce its allotments for futures and decrease its futures price, resulting in lower profits. In this section we focus on the impact of the relationship between the consumers' and the winemaker's risk-adjusted discount rates, θ and ϕ , respectively. It is stated earlier that the wine industry is a unique market where the winemakers' risk concern is higher than that of the consumers; therefore, whereas Proposition 2 provides a comprehensive report, our discussion focuses on the representative case where $\theta > \phi$.

Proposition 2 states that as a winemaker's risk concern grows with smaller values of ϕ and/or increasing values of $\theta - \phi$, she allocates a higher percentage of wine for early sales in the form of wine futures. This is a common behavior we can observe in practice. Small Bordeaux wineries with smaller overall profitability and higher risk concerns (e.g., Evangile, Clos Fourtet, Troplong Mondot, and Cheval Blanc) allocated more than 25% of their wine as futures on average between 2006 and 2011. During the same time interval, smaller risk winemakers such as Cos d'Estournel and Leoville Poyferre sold less than 15% of their wine on average in the form of wine futures. The most profitable winemakers with a higher degree of fluctuations in returns, Pavie and Angelus, sold approximately 20% of their wine in the form of futures. Finally, Proposition 2 demonstrates that the behaviors of the optimal futures price and expected

profit are not monotone in ϕ and $\theta - \phi$; they are parameter dependent.

4.4.2. The Impact of Barrel Score. Proposition 2 shows that when $\theta > \phi$, the optimal number of cases reserved for sale as futures (q_f^*) increases in s_1 . One might intuit that a higher barrel score can cause the winemaker to reduce her futures allocation to exploit retail consumers; however, our model assumes no bias (i.e., $E[\tilde{s}_2 | s_1] = s_1$); therefore, the winemaker prefers cash early than cash at the retail stage. Thus, the winemaker increases q_f and α with higher barrel scores. When consumers are more risk averse than the winemaker, however, the impact of barrel scores can be reversed. In this case, the winemaker can reduce its allocation to the futures market to exploit consumers' higher willingness to pay at the retail stage; thus, q_f^* can decrease with higher barrel scores. The result is influenced by the slope of the market size function $M(s_1)$; q_f^* increases in s_1 if the slope of $M(s_1)$ is large and decreases in s_1 if the slope of $M(s_1)$ is small.

Our model considers that the market size increases with higher barrel scores, reflecting the hype effect commonly observed in the wine industry. It is important to note that, even if the market size were not to be impacted by the barrel score and defined as constant (by defining $M(s_1) = M$), most of the results would continue to hold, and only a few of our results would change. First, the amount of wine allocated as wine futures (q_f^*), price of wine futures (p_f^*), and the optimal expected profit all increase in s_1 when $\theta = \phi$. Second, the amount of wine futures (q_f^*) strictly decreases in s_1 when $\theta < \phi$, and the futures price (p_f^*) increases monotonically in s_1 when $\theta < \phi$.

A final observation is that, regardless of the relative values of θ and ϕ , the winemaker's risk-adjusted expected profit continues to increase with higher barrel scores. However, the expected profit does not follow the same monotone behavior in β , necessitating further analysis.

4.4.3. The Impact of Consumer Heterogeneity.

We next examine the impact of consumer heterogeneity on the optimal decisions and the winemaker's profitability for the case of $\theta > \phi$. In our model, the definition of β in the Gumbel distribution corresponds to the dispersion of consumer utilities (i.e., the variance of ε_f , ε_r and ε_0 is $(\pi\beta)^2/6$). Lower values of β reflect the situation in which the consumers have a similar preference toward purchasing wine as futures (as well as the alternatives of purchasing a bottle or no purchase); therefore, their utility of buying wine as futures is relatively close to the mean. On the other hand, a larger value of β corresponds to the case where the consumers are less homogeneous toward their willingness to consume wine as futures; in this scenario some consumers have a very high utility of buying wine as futures relative to the mean, and some consumers have a very low utility relative to the mean.

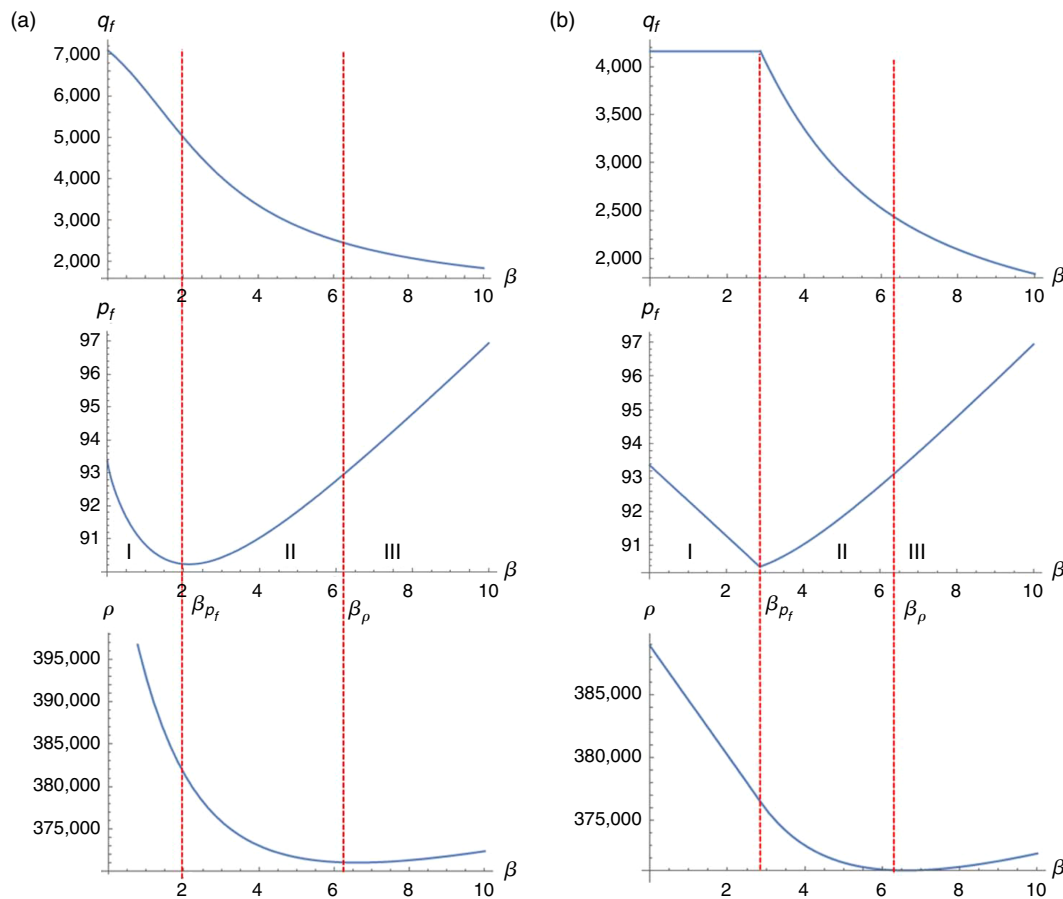
Proposition 3 shows that both the optimal futures price and the expected profit expressions are non-monotonic in consumer heterogeneity. We define β_{pf} and β_p as the values of consumer heterogeneity where the optimal futures price and expected profit

expressions change their direction from decreasing to increasing functions, respectively.

PROPOSITION 3. When the consumer preference of purchasing wine as futures is higher than the winemaker preference from selling wine as retail, i.e., $\theta > \phi$, (a) the optimal futures price p_f^* in (6) and the expected profit ρ^* in (7) are convex in β , and (b) the optimal futures price switches from decreasing behavior to an increasing behavior before the optimal expected profit, i.e., $\beta_{pf} \leq \beta_p$.

The consequence of Proposition 3 is that the optimal decisions of the winemaker can be classified in three regions of consumer heterogeneity as depicted in Figure 6 for the 2008 vintage of Cheval Blanc (with parameters $s_1 = 96$, $M(s_1) = 5,070.74$, $Q = 4,165$, $\theta = 0.9726$, and $\phi = 0.8692$; part (a) of the figure shows the results when the supply constraint is not binding, and part (b) shows when it is binding). In region I where consumers are homogeneous (with values of β that are smaller than β_{pf}), as the heterogeneity among the consumers of wine futures increases, the winemaker decreases the price and the allocation of wine futures, resulting in a lower profit. This case reflects the scenario where some consumers that have lower

Figure 6 (Color online) Impact of Consumer Heterogeneity β on the Optimal Values of Percentage of Wine Allocated as Futures, Futures Price, and the Profit for the 2008 Cheval Blanc Vintage



willingness to pay for wine futures leave the market; thus, the winemaker is forced to decrease its price and allocation of wine futures to accommodate for the loss in demand. This behavior causes the profit to decrease. On the other hand, in region III, where the consumer heterogeneity is high and is above the threshold β_p , the winemaker takes advantage of the consumers that have high willingness to pay for wine futures by charging them a higher futures price and at the same time decreasing the wine futures allocation and increasing the profit. Region II corresponds to the case where the heterogeneity among the consumers is not large enough for the winemaker to take full advantage of the consumers with high willingness to pay; specifically, we have $\beta_{pf} < \beta < \beta_p$. In this region, the winemaker increases the price of wine futures, but the increase is not significant enough to cover the loss of consumers with lower willingness to pay, resulting in a decline in profits.

Proposition 3 presents an important result regarding the impact of consumer heterogeneity, and Figure 6 demonstrates this effect. In marketing literature, it is commonly reported that monopolistic firms are better off when consumers are homogeneous, because these firms would capture all the surplus and do not need to engage in price reduction and/or discrimination; rather, these monopolistic firms would take actions (e.g., bundling) to create an even more homogeneous market (Carlton and Perloff 2010, Varian 2009). Contrary to this common notion, the winemaker can achieve a higher level of profitability when the market is filled with consumers that are heterogeneous as is the case in region III of Figure 6. In the presence of heterogeneous consumers, there are consumers with lower willingness to pay for futures. Because these consumers find wine futures less attractive, the winemaker can charge a higher price for its wine futures to take advantage of the consumers whose valuations of wine futures are high. This reaction can be seen among Bordeaux wineries. The economic crises in Europe and the United States and the recent emergence of the Asian economy exemplify a global market with higher levels of heterogeneous consumer base (distributors, collectors, auction houses, governments reserving limited stock, etc.). Bordeaux winemakers have been setting higher wine futures prices in recent years to take advantage of the increasing consumer heterogeneity as a consequence of the affluent Asian market. Moreover, these Bordeaux winemakers allocate more wine for retail sales with the hope that the traditional economic powerhouses would recover from the recent economic crises and their consumers would reenter the market at the retail stage. The consumer base for the small and artisanal U.S. winemakers differ from the traditional Bordeaux fine-wine producers as they have significantly

more homogeneous consumers. Thus, their environment is better represented with the behavior that can be observed in region I of Figure 6, in both parts of (a) where the supply constraint is not binding and in (b) where the supply is binding with limited production. Section 5 demonstrates this behavior for the Bordeaux winemakers and for an example U.S. artisanal winemaker.

The analysis presented here ignores the impact of speculators in the futures market. When incorporated, as shown in the online appendix (available as supplemental material at <http://dx.doi.org/10.1287/msom.2015.0529>), speculators benefit the winemaker because the firm does not have to reduce the futures price below speculators' price preference, and sell more wine in the futures market, leading to higher expected profits.

5. Empirical Analysis

We begin this section by presenting the results of empirical analysis of the MNL model presented in §4. We then use our calibrated model to assess the financial impact of the wine futures market.

Our analytical model describes the futures price as in (2); specifically, the wine futures price can be explained with a bivariate model $p_f = \theta s_1 + \beta x$ where $x = \ln[(1/2)[M(s_1)/q_f - 1]]$, relying on barrel score s_1 and the natural logarithm of the ratio $(1/2)[M(s_1)/q_f - 1]$. Using the Bordeaux winery data, Table 4 shows how well our model predicts the wine futures prices, and Figure 7 demonstrates the fit between the actual and forecasted futures prices.

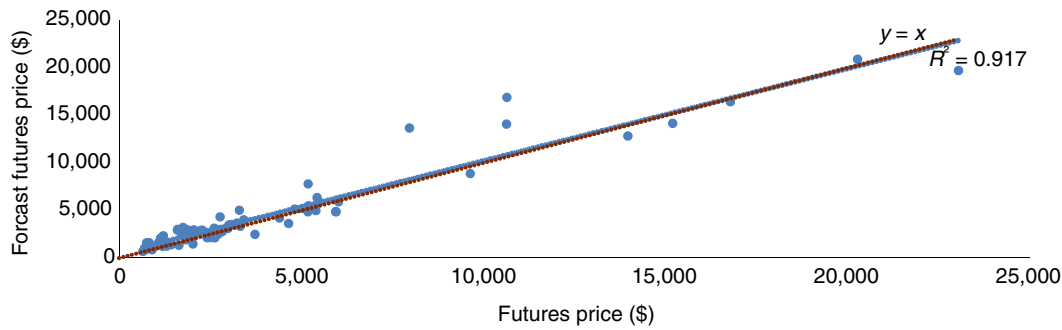
The statistical analysis presented in Table 4 provides four conclusions. First, our construct of the analytical model presented in §4 finds strong empirical support with its adjusted R^2 value of 0.63. Second, the two variables that explain the wine future prices, barrel scores, and the natural logarithm of the ratio $(1/2)[M(s_1)/q_f - 1]$ are statistically significant at the highest level possible, corresponding to less than 1%. Third, Table 4 provides estimates of two critical parameters: the consumers' risk-adjusted discount rate θ is estimated to be equal to 0.9726, and the scale parameters of the Gumbel distribution representing

Table 4 Summary of Linear Regression Results for the Normalized Values of Futures Prices vs. the Normalized Values of Barrel Scores and the Natural Logarithm of the Ratio $(1/2)[M(s_1)/q_f - 1]$

Parameter	Coefficient	(p-value)
Barrel score (\hat{s}_{1it})	0.9726	$(1.21 \times 10^{-17})^{***}$
x	23.5275	$(8.67 \times 10^{-7})^{***}$
Adjusted R^2	0.63	

***Statistically significant at the 1% level.

Figure 7 (Color online) Fit Between the Normalized Actual Futures Prices and Forecasted Futures Prices



consumer heterogeneity β is estimated to be equal to 23.5275. Fourth, the estimated value of the consumers' risk-adjusted discount rate θ reveals that buyers of wine futures are not strongly risk averse. To illustrate this, let us compare the estimated value of θ with the risk-neutral discount rate, which can be evaluated as $(1 + r_f)^{-1}$. Considering the European Central Bank interest rate of 0.025 as the risk-free rate $r_f = 0.025$ for the Bordeaux wineries, the risk-neutral discount rate would be equal to $(1 + r_f)^{-1} = 0.9756$. The coefficient of variation of the barrel score is $c_v = 0.0298$. In §4, the consumers' risk-adjusted discount rate is defined as $\theta = (1 + r_f)^{-1}(1 - \gamma c_v)$; solving this equation for γ reveals a risk aversion coefficient of $\gamma = 0.1035$. Our estimate for the risk-adjusted discount rate $\theta = 0.9726$ is close to the risk-neutral discount rate 0.9756, representing that buyers of wine futures are risk averse; however, the degree of risk aversion is not strong.

We next present a correlation analysis between the Robert Parker barrel scores (s_1), allocation percentages assigned by winemakers (α), futures price (p_f), and the forecasts using the linear regression model for the allocation decision (α_{jt}) and the regression model based on the MNL model for the futures price decision (f_{jt}). Table 5 presents the summary of correlation analysis between these five variables.

Several conclusions can be made from the correlation analysis presented in Table 5. First, the barrel score (s_1) shows a 60% positive correlation with the winemaker's allocation decision (α) and a 47% positive correlation with the futures decision (p_f). This is a significant amount of correlation, once again justifying the analytical model established in §4. Second, the

actual and predicted percentages of wine allocated for futures shows a 79% positive correlation. Third, the actual and predicted futures prices exhibit a 96% positive correlation. As a consequence, we can conclude that (1) there exists a strong relationship between the barrel scores, the percentage of wine allocated for the futures market, and the futures price; (2) the relationships between these three variables are captured well in our statistical analysis; and (3) the empirical analyses provide ample support validating our analytical model.

We next analyze the financial impact of the wine futures market. In the absence of a futures market, the winemaker is forced to sell all of its wine in the retail market. We describe the profit that can be obtained in the absence of a futures market by ρ^0 which can be calculated by substituting $q_f = 0$ in the profit expression in (3) as $\rho^0 = \phi s_1 Q$. The percentage impact of wine futures on the profit of the winemaker is

$$\Delta\rho = \frac{\rho^* - \rho^0}{\rho^0} \times 100\% = \frac{M(s_1)\beta W(e^{(\theta-\phi)s_1/\beta}/2e)}{\phi s_1 Q} \times 100\%. \quad (11)$$

The directional impact of an increase in β or s_1 on $\Delta\rho$ is parameter-dependent. However, it is clear from (11) that the value of a futures market is greater for a highly risk-averse winemaker (i.e., $\Delta\rho$ is decreasing in ϕ).

Table 6 reports the results of the analysis regarding the financial impact from the presence of the wine futures market on the 12 Bordeaux wineries examined

Table 5 Correlation Coefficients Between Barrel Scores, Futures Allocation Percentage, Forecasted Futures Allocation Percentage, Futures Price, and Forecasted Futures Price

	Barrel score (s_1)	Allocation (α)	Futures price (p_f)	Forecast allocation (α_{jt})	Forecast futures price (f_{jt})
Barrel score (s_1)	1				
Allocation (α)	0.600	1			
Futures price (p_f)	0.467	0.326	1		
Forecast allocation (α_{jt})	0.772	0.785	0.328	1	
Forecast futures price (f_{jt})	0.476	0.286	0.958	0.330	1

Table 6 Financial Benefit from the Presence of a Wine Futures Market in Winemaker Profits

Winemaker	ϕ	Min α	Max α	Avg α	Min $\Delta\rho$	Max $\Delta\rho$	Avg $\Delta\rho$
Angelus	0.96936308	6.90	49.35	18.71	2.16	14.45	5.71
Cheval Blanc	0.86918809	8.59	71.25	39.26	3.23	24.81	13.91
Clos Fourtet	0.88701179	9.48	45.85	29.18	3.38	15.56	10.21
Cos d'Estournel	0.87673835	4.96	43.74	21.15	1.78	14.84	8.21
Ducru Beaucaillo	0.88961788	14.23	65.63	39.45	4.88	22.06	13.53
Duhart Milon	0.79816123	14.80	47.05	26.24	6.47	19.03	10.92
Evangile	0.85688923	21.40	100.00	64.03	7.84	41.81	22.70
Leoville Poyferre	0.90829830	6.94	38.90	23.45	2.43	12.74	7.91
Mission Haut Brion	0.94221522	17.19	80.46	38.04	5.59	24.33	11.80
Pavie	0.97247639	2.08	31.45	12.30	1.17	14.75	6.27
Pichon Lalande	0.84258235	6.40	49.09	29.20	2.53	18.54	11.01
Tropelong Mondot	0.83791897	10.86	68.99	42.55	4.22	25.41	16.11
Weighted average				27.65			10.10

in this study. Let us briefly describe how the impact of the wine futures market is estimated. Consumers' valuation of fine wine is calculated based on the CVaR approach described in §4. As noted above, our data shows that consumers do not exhibit a strong degree of risk aversion with $\gamma = 0.1035$ and the consumer's risk-adjusted discount rate is estimated at $\theta = 0.9726$.

We employ the capital asset pricing model (CAPM) to determine the risk-adjusted discount factor for a winemaker. We describe the winemaker's risk-adjusted discount factor as $\phi = (1 + r_f + \gamma(r_m - r_f))^{-1}$ where r_m is the market return; therefore, $r_m - r_f$ is the risk premium, and γ is the winemaker's risk measure following the CAPM approach. We evaluate market returns through the average annual percentage change in the Liv-ex 100 index from 2006 to 2013; thus, we use $r_m = 0.1043$. Each winemaker's risk measure is calculated as $\gamma = \text{COV}(r_j, r_m) / V(r_m)$ where the covariance between the returns of the specific winemaker (r_j) and the market returns (defined as $\text{COV}(r_j, r_m)$) is divided by the variance in market returns (defined as $V(r_m)$). The market size of each winemaker is provided by Liv-ex and is described as $M(s_i) = M(1 + (2/(101 - s_i)))$. Our model describes consumer heterogeneity through a Gumbel distribution with a mean of zero and a dispersion parameter described by β . Table 4 provides the estimate for the consumer heterogeneity parameter β , and we use $\beta = 24$ in our analysis.

Table 6 presents the results for the 12 Bordeaux winemakers examined in this study. Min $\Delta\rho$, Max $\Delta\rho$, and Avg $\Delta\rho$ in Table 6 represent the minimum, maximum, and average percentage profit improvement from the wine futures market between 2006 and 2011 vintages, respectively. It shows that Bordeaux winemakers benefit from the presence of wine futures by increasing their profits by 10.10% on average. The average percentage improvement in profits ranges from 5.71% to 22.70%. The minimum financial benefit occurs at the low barrel scores as observed at Pavie

with a 1.17% profit improvement; the highest benefit is observed with high barrel scores at Evangile with a 41.81% profit improvement. From the analysis in Table 6, we can conclude that the presence of a wine futures market creates a significant financial benefit to the Bordeaux winemakers.

Table 6 also demonstrates the percentage of wine that should be allocated as wine futures. Min α , Max α , and Avg α in Table 6 represent the minimum, maximum, and average percentage of wine, respectively, that should be allocated to be sold in the form of wine futures among the 2006–2011 vintages. Our analysis shows that these wineries should allocate on average 27.65% of their wine as futures, with a minimum of 12.30% and a maximum of 64.03% on average. When barrel scores are low, we observe less wine to be allocated for wine futures, with the minimum occurring at Pavie with 2.08%. High barrel scores can create a lucrative environment for these fine wine producers, and Evangile allocated 100% of its production for sale in the form of wine futures after a barrel score of 98 in 2009. Thus, we can conclude that selling wine while aging in the barrel in the form of wine futures provides a good operational and financial lever to these winemakers.

We next examine the potential impact of wine futures for the U.S. artisanal/boutique winemakers. Specifically, we demonstrate the financial benefit using the winemaker Heart & Hands Wine Company that motivated our study. It should be noted here that Bordeaux fine-wine producers are considered to have a wide variety of buyers, including affluent consumers, collectors, distributors, and auction houses raising funds for charities. Small and artisanal winemakers in the United States are expected to have (1) higher risk aversion than Bordeaux winemakers, leading to lower values of ϕ , and (2) a more homogeneous consumer base, represented with a smaller dispersion parameter in our Gumbel distribution. Both of these observations are captured in our analysis. For

U.S. winemakers, we estimate the consumers' valuation by using the risk-free rate of return based on the 12-month U.S. Treasury Bond, which provides a return of $r_f = 0.00012$. Thus, $\theta = (1 + r_f)^{-1}(1 - \gamma c_v) = 0.99659$ for the U.S. wine consumers. We follow the same approach to estimate the winemaker's risk preference ϕ toward the value of cash today versus cash in the retail stage; comparing the returns of the firm with the market returns, we have $\phi = (1 + r_f + \gamma \cdot (r_m - r_f))^{-1} = 0.76595$. Because consumers are more homogeneous compared to the Bordeaux winemakers, we describe consumer heterogeneity through a Gumbel distribution with a mean of zero and a smaller dispersion parameter at $\beta = 10$.

Table 7 presents the results for Heart & Hands Wine Company's potential financial benefit from a wine futures market, enabling the firm to sell its wine early while aging in barrels. Because Robert Parker and the *Wine Advocate* do not have reviews of Heart & Hands Wine Company, wine ratings for two varietals, Pinot Noir and Riesling, are obtained from *Wine Spectator*. As can be seen from the results presented in Table 7, a wine futures market can create an even greater financial benefit for small and artisanal U.S. winemakers than the Bordeaux wineries. Heart & Hands Wine Company improves its profit ($\Delta\rho$) by 13.87% on average with a minimum financial benefit of 12.97% and a maximum financial benefit of 15.59%. Despite having consistently lower barrel scores than the Bordeaux wineries, Heart & Hands Wine Company should allocate a significantly larger percentage of its wine as futures (α): 55.03%. Thus, we can make two conclusions from this analysis: (1) The U.S. winemakers have a more pressing need for a futures market (demonstrated with higher percentages allocated for futures), and (2) U.S. winemakers would benefit financially even more than the Bordeaux producers.

Our analysis of the financial impact of a wine futures market presents several distinct characteristics separating the type of benefits Bordeaux wineries and U.S. artisanal winemakers experience in their

businesses. First, the French winemakers benefit from the heterogeneity in its consumer base. Because of the reputation of Bordeaux winemakers, there is a consumer segment with a higher willingness to pay; Bordeaux winemakers price their wine futures high enough to extract the largest value from such consumers. This can be seen from the fact that the threshold dispersion parameter β_p is almost always lower than the dispersion parameter $\beta = 24$. As a consequence, Bordeaux winemakers benefit even further with higher expected profits and higher futures prices through increasing heterogeneity. The U.S. artisanal winemakers are the opposite, where their dispersion parameter $\beta = 10$ is almost always below the threshold dispersion parameter β_{pf} . Thus, increasing consumer heterogeneity has a different effect on the U.S. artisanal winemakers as it decreases their futures allocation, futures price, and expected profit. Thus, when the U.S. artisanal winemaker expands its consumer base to achieve a higher heterogeneity in its customers' willingness toward purchasing wine in the form of futures versus bottles, it would initially experience reduced benefits. However, when its reputation is as established as the Bordeaux winemakers, then its profits are likely to increase as much as the French wineries. Table 7 presents the futures allocation and the financial benefit when Heart & Hands Wine Company achieves the same consumer heterogeneity with the Bordeaux wineries at $\beta = 24$. Whereas the percentage of wine allocated for futures decreases from 55.03% to 31.96%, Heart & Hands Wine Company achieves a higher profit improvement with 14.95% (exceeding 13.87%).

6. Conclusions

This paper examines the implementation of advance selling in the wine industry as a form of operational flexibility to mitigate quality rating risk. We investigate the impact of various exogenous factors that influence the winemakers' allocation between futures and retail sales, and its pricing decisions.

Our study makes three contributions. First, we develop an analytical model that incorporates two forms of uncertainties into the decisions regarding advance selling: (1) uncertain consumer valuations of wine futures and bottled wine, and (2) the bottle score that is assigned to the wine at the end of the production process. We employ a CVaR approach in determining the consumers' risk-adjusted discount rate; their valuation of wine futures is influenced by the expected bottle score (equal to the barrel score), the coefficient of variation in bottle score, and the risk-free rate of return. We provide closed-form expressions for the optimal allocation and pricing decisions.

Table 7 Financial Benefit from the Presence of a Wine Futures Market at Heart & Hands Wine Company

Varietal	Vintage	$\beta = 10$		$\beta = 24$	
		α	$\Delta\rho$	α	$\Delta\rho$
Pinot Noir barrel reserve	2007	53.26	13.74	31.25	15.20
	2008	55.74	13.95	32.29	14.96
	2009	54.42	13.63	31.53	14.60
	2010	51.23	12.97	29.82	14.08
Riesling	2008	59.25	14.92	34.40	16.09
	2009	62.63	15.59	36.20	16.61
	2010	57.09	14.29	33.07	15.32
	2011	61.57	15.41	35.67	16.52
Weighted average		55.03	13.87	31.96	14.95

These closed-form expressions enable us to investigate the underlying factors that influence the winemaker's decisions. Our study provides a comprehensive analysis regarding the impact of each factor on the optimal quantity and price of wine futures.

Our second contribution relates to the impact of consumer heterogeneity on the optimal allocation and pricing decision. Contrary to common belief that the winemaker may be better off when consumers are more homogeneous, our results demonstrate that the winemaker can achieve greater profits when the market is filled with consumers that are heterogeneous. As the consumers with the lower willingness find wine futures less attractive, the winemaker can charge a higher price for its wine futures and take advantage of the consumers whose valuations of wine futures are high. Such circumstances reflect the state of the world economy today. For example, despite the economic crises in Europe and the United States, there is a strong Asian demand for fine wine; thus, there is a highly heterogeneous consumer base for the French wineries. In this recent economic environment, the Bordeaux winemakers continue to set a higher price for their wine futures and take advantage of the increasing affluence in this Asian market. Moreover, these winemakers also allocate more wine for retail sales with the hope that the traditional economic powerhouses would recover from the economic crises, and its consumers reenter the market at the retail stage.

Third, we test our model by illustrating the impact of barrel scores on the quantity and price of wine futures through an empirical analysis using data from Bordeaux wineries. We show that barrel scores play a statistically significant role in estimating the percentage of wine allocated as futures and the futures price. Moreover, our numerical analysis illustrates the financial impact of the futures market on Bordeaux wineries with an average of 10.10% profit improvement in our sample. Using data from a small U.S. winemaker, we find that despite consistently lower barrel scores, small and artisanal winemakers can benefit from a futures market more than Bordeaux wineries because of their higher risk preference. Our empirical conclusions have important implications for policy makers and the U.S. wine industry. For example, with its 416 licensed small and artisanal winemakers, the state of New York generates \$4.8 billion revenues from its wine industry, bringing more than \$400 million in tax revenues. In 2014, Governor Andrew M. Cuomo of New York organized two summits where he indicated the desire to develop creative ways for growth and profitability in this industry with an urgency to invest in quality improvements. Currently, there is no electronic futures exchange for U.S. winemakers. Our investigation illustrates, however, such an electronic futures exchange would enormously benefit small and artisanal winemakers in the United States.

There are several directions this study can be extended for future research. First, Bordeaux winemakers cannot lease farm space to produce fine wine because of restricted growing regions and the requirement to report appellation in wine labels. In the United States, however, winemakers have the ability to lease farm space to grow additional grapes and increase the initial production quantity. Our model can be incorporated in a study where the U.S. winemaker's leasing decisions are influenced by the presence of futures markets. Such studies require incorporating additional uncertainty and the risk associated with crop yield fluctuations. Second, our study assumes that there is only one barrel score; whereas Robert Parker's ratings serve as the worldwide standard, multiple expert barrel scores can create a dispersion on the consumer's perception of bottle scores and quality. Our model can be extended to incorporate multiple scores reflecting variations in quality perceptions. Third, the timing of the barrel tastings cannot be influenced by the winemaker. However, there might be other agricultural products where the producer can alter the quality signal released to the market by influencing the timing of the review.

Supplemental Material

Supplemental material to this paper is available at <http://dx.doi.org/10.1287/msom.2015.0529>.

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