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## Prices as Quality Signals: Evidence from the Wine Market

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## Abstract

In this paper we empirically analyze whether prices serve as signals. Specifically, and following the hypothesis by Bagwell and Riordan (1991), we examine whether (1) higher quality and (2) low consumer information levels about quality are associated with prices that are above the full information equilibrium. We refer to two price samples of identical wines and analyze the difference between both. The first sample consists of prices for informed wholesalers who can taste the wines before purchase. The second sample comprises retail prices for the imperfectly informed public. We find support for the Bagwell-Riordan model, i.e., price signals respond positively to wine quality and negatively to increasing information. For our sample, the information effect by far dominates the quality effect.

**KEYWORDS:** wine, price signals

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## 1. Introduction

In many markets sellers of a product are better informed about a good's quality than buyers resulting in the well known 'lemon problem' (Akerlof, 1970). Since it is impossible for many consumers to distinguish a high quality good from a low quality one, both goods sell for the same price. A growing body of literature has shown that the lemon problem is an important issue for experience and credence goods for which quality cannot be ascertained before consumption.<sup>1</sup> Food items and environmentally friendly products are one of the most investigated goods within this category (e.g., Karl and Orwat, 1999; McCluskey and Loureiro, 2000; Loureiro et al., 2003).

However, as shown first by Spence (1973), producers can signal quality. High quality can be signaled by offering warranties (Spence, 1977; Grossmann, 1980), by advertising (Milgrom and Roberts, 1986) or by reputation (Shapiro, 1983). Theoretical models of prices as quality signals were first developed by Farrell (1980), Wolinsky (1983) and especially by Milgrom and Roberts (1986), Tirole (1988) and Bagwell and Riordan (1991).

As first shown by Bagwell and Riordan (1991) for a two-seller two-quality monopoly model, prices can signal quality given that the high-quality product is more costly to produce than the low-quality product. At the incomplete information equilibrium, the firm producing low-quality chooses the full-information price whereas the high-quality firm distorts its price upwards compared to the full-information price for high quality.

The current paper focuses on the role of prices as quality clues and is inspired by the theoretical analysis of Bagwell and Riordan (1991). We refer to the wine market to explore the role of the price as a quality signal conditional of wine quality and on the degree of consumer information. Like prior empirical studies, we do not have any information about marginal production cost. However, we circumvent this problem by drawing on two different datasets that include identical wines, i.e., wines marketed under the same label and registration number,<sup>2</sup> sold on different markets. In one market, wines are tasted before purchase and buyers are (almost) fully informed wholesalers. The other market is the retail market. Here, most buyers do not taste the wines before purchase and

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<sup>1</sup> The quality of an experience good, such as wine, cannot be judged before consumption (Nelson, 1970). The quality of credence goods, such as services from automobile mechanics or dentists, cannot be accurately evaluated even at a certain time after consumption (Darby and Karni, 1973).

<sup>2</sup> By "the same wine," we refer to a batch of wine marketed under one label. German wine labels are very detailed and contain information about the producer's name and location, grape variety, alcohol content, sugar content bracket of the grapes at harvest (*Kabinett*, *Spätlese* etc.), as well as the vineyard the grapes originate from. After passing a mandatory chemical analysis and a tasting each wine receives an "Amtliche Prüfnummer," a registry number that appears on the label. It is the registry number that enables one to identify a wine.

only a small fraction of all buyers are informed. In both markets prices are set by producers.

When analyzing the price difference between the two samples we find strong support for the Bagwell-Riordan model. The price signal varies proportionally with the wine's quality. In addition, the price premium falls non-linearly when the fraction of informed buyers increases.

This paper is organized as follows. Sections 2 and 3 provide an overview over the theoretical and empirical literature, respectively. Section 4 presents the dataset and Section 5 describes the model. In Section 6 we report the results; we summarize our main findings in Section 7.

## **2. Theoretical Literature**

Following the logic of Nelson (1970 and 1974), a winery can signal high quality by setting the price below the full information price. Quality signaling by underpricing is dependent on the condition that present profits foregone are lower than profits from future sales (at higher full-information prices). For the signal to be credible the price must be "sufficiently low", i.e., lower than a winemaker producing low-quality wine can possibly go.

This, however, may be too low for the winemaker offering high-quality wine for two reasons. First, given the fact that wine is regularly sold within one year after production, the time span to earn sufficient future profits to offset the initial loss incurred by the signal is limited. Second, high-quality wine is typically produced with higher marginal cost than low quality wine.<sup>3</sup>

This cost difference is the basis of the "Schmalensee effect" (Schmalensee, 1978). Since a low-quality winemaker wants to be mistaken for a high-quality winemaker, he will charge the same price as the high-quality winemaker. One way for the high-quality winemaker to distinguish himself from the mimicking low-quality winemaker is to openly exhibit his high production cost in a way that is too costly for the low-quality producer. For instance, he can use a helicopter to dry his vineyard before harvesting (e.g., Mahenc and Meunier, 2006).<sup>4</sup>

Farrell (1980, Chapter 2) goes one step further and shows that it is the presence of informed buyers that attracts high-quality producers and thereby

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<sup>3</sup> A different model of initial underpricing developed by Bergemann and Välimäki (2006) draws on the fact that each consumption also incorporates an element of information that is relevant for future purchases ("experimental consumption"). The value of the consumption-related information is determined endogenously and dependent on the future price of the good. Bergemann and Välimäki show that optimal prices in niche markets are initially low and increase subsequently.

<sup>4</sup> Tirole (1988) developed a signaling model that combines both the "Nelson" and the "Schmalensee effect."

establishes the price as a quality signal to uninformed buyers. On the one hand, firms that signal high quality with prices that are above the full-information level will gain sales from uninformed customers who believe the signal. On the other hand, they will also lose sales from informed customers. Bagwell and Riordan (1991) analyze a two-firm and two-quality market<sup>5</sup> and argue that high-quality producers can credibly signal the quality of a new product with premiums above the full information profit-maximizing price as long as low-quality producers cannot mimic this strategy. This conclusion is based on the assumption that a loss of customers hurts low-quality producers more than it does high-quality producers.

Over time, as information about the good proliferates into the market and the fraction of uninformed customers falls, the price loses its function as quality signal to uninformed buyers and approximates the full information price. Thus, the ‘quality premium’ disappears. In other words, the remaining uninformed agents free-ride on the learning of informed agents (see also Grossman and Stiglitz, 1980).

Given the possibility that competition may dissipate the rents from signaling, Daughety and Reinganum (2007a, 2007b) examine whether quality signaling via prices can also occur in markets with several competing sellers. For an oligopolistic market, they show that incomplete information about sufficiently horizontally differentiated products considerably softens price competition by firms and is consistent with price-induced quality signaling.

Janssen and Roy (2007) investigate the question whether horizontal product differentiation is necessary for price competition to soften and thus allow for quality signaling through prices. They show that price signaling occurs even when products are not horizontally differentiated and firms are engaged in a stiff price competition.

### 3. Empirical Literature

On the empirical side, there are numerous marketing and economic papers that analyze the degree and the development of quality-signaling through prices on particular markets.

Most authors examine the correlation between price and quality across a large variety of consumer goods (e.g., Riesz, 1978; Geistfeld, 1982; Hjorth-Andersen, 1984; Gerstner, 1985). The underlying theory is that the equilibrium correlation between price and quality increases with the level of information in the market and is equal to one when consumers are fully informed about quality. The typical findings are that, although most correlations are positive, there is a

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<sup>5</sup> Daughety and Reinganum (1995) provide a model with a continuum of qualities.

large variance in price-quality correlations with some coefficients even being negative.

For instance, Tellis and Wernerfelt (1987) find that the correlation between price and quality is stronger on markets with a wide price spread. Assuming that more consumers search and are better informed as the spread in prices at which goods are sold increases they infer that prices serve as quality signals on these markets.

Similarly, Caves and Greene (1996) show that the quality-price correlation coefficients are determined by the amounts and types of information that consumers gather to select among brands. On the one hand, they find quality-price correlations to be higher for product categories that include more brands and presumably give greater scope for vertical differentiation. Caves and Greene infer that vertically differentiated markets stimulate consumer search and increase the level of information. On the other hand, they find price-quality correlations to be low for innovative and convenience goods suggesting that here prices signal quality.

Curry and Riesz (1988) show that during a product's life cycle prices converge and decline. The mean price, the price range as well as the quality-price correlation fall subsequent to a new product's introduction. However, it is not clear whether this is due to an increasing fraction of informed buyers. The results may as well be the result of a substantial decline in marginal costs over time.

Miller et al. (2007) examine the quality-price relation for 2001 Napa Cabernet Sauvignon wines and find that wine quality only partially explains the enormous variation in wine prices. This, according to the authors, suggests the existence of a substantial degree of signaling.

Although quality-price correlations are a convenient tool to analyze whether a particular market is outside of its full-information equilibrium, this method is inappropriate to empirically test the Bagwell-Riordan (BR) model for several reasons. First, the correlation coefficient does not provide any information about the nature of the disequilibrium; under- and overpricing is indistinguishable. Second, price-quality correlations only provide information on a market as a whole; quality signaling of particular brands cannot be analyzed. As a result, one is unable to empirically examine the BR model of overpricing where the signal size is assumed to be a function of quality. Third, without any information about marginal cost it is speculative to interpret falling prices over time as induced by consumer learning (e.g., Curry and Riesz, 1988). The same effect could have been caused by increasing competition and/or falling marginal cost. Hence, it is apparent that the ideal dataset includes information on marginal production costs as well as on the information level of each consumer group.

These shortcomings of correlation-coefficient analyses are addressed by Roberts and Reagans (2007). They analyze whether the price-quality correlation

of New World wines sold in the U.S. is influenced by the degree of critical exposure. Instead of relying on correlation coefficients they employ a model that regresses the wine price on different measures of media attention, i.e., public information. This allows the authors to focus on the impact of public information about the individual vintner. They show that the slope of the relationship between quality ratings and wine prices is moderated by the amount of attention that producers receive.

In two related papers Ashenfelter et al. (1995) and Ashenfelter (2008) examine the price development of Bordeaux *grands crus* wine vintages over time. First, the authors calculate a “full-information price” as a function of temperature and precipitation. Then they show that directly after the release of the wine auction prices substantially deviate from the respective full-information price. However, as more information about the wines’ quality becomes available (Bordeaux *grands crus* are very tannic upon release and need to mature for five to eight years in order to be drinkable), auction prices steadily move towards the full-information equilibrium.

#### 4. Data

We circumvent the problem of lacking cost information using two different datasets that contain identical wines; in both samples prices are set by producers.

The first dataset contains wholesale prices from the Mainz Wine Trade Fair (*Mainzer Weinbörse*). Once a year for two days, the fair showcases the wines of about 100 VDP estates.<sup>6</sup> The fair is open to the trade only. Our dataset covers the fair years 1993 to 2001 and contains a total of 3399 wines from the German wine regions Mosel, Rheingau and Nahe (*Mainzer Weinbörse*, 1993-2001). Given the nature of the buyers (wine-experienced wholesalers) and the fact that all wines can be tasted before purchase we assume that buyers are characterized by an extraordinarily high information level suggesting that wholesale prices can be deemed (very close to) “full information prices.”

The second dataset consists of retail prices of the same wines when they are bought at the estate. The prices are published annually in the Gault Millau wine guide for Germany (Diel and Payne, 1994-2002). Covering the same time span and regions the Gault Millau lists more than 7000 wines. However, only 1105 of these wines are identical with the first dataset.

Customers that buy retail are typically substantially less informed about the wines’ quality than the professionals that frequent the Mainz Wine Fair. In addition, in almost all cases wines are not tasted before purchase. We therefore

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<sup>6</sup> In Germany, most high-quality wine producers are organized in the Association of German Quality Wine Estates (*Verband Deutscher Prädikatsweingüter VDP*).

assume that only a small fraction of all buyers are informed. Table 1 reports selected descriptive statistics of the price data.

*Table 1*  
**Descriptive Statistics of Wine Prices**  
in €/0.75 liter bottle

	n	minimum	maximum	mean	standard deviation
<i>Gault Millau Sample (retail, mostly uninformed)</i>					
all <sup>a</sup>	1105	3.32	493.87	16.54	36.80
all (<€300)	1102	3.32	270.96	15.46	29.97
<i>by quality level</i>					
quality wine	198	3.32	38.34	6.57	4.24
Kabinett	342	4.35	14.31	6.71	1.78
Spätlese	408	5.11	38.35	10.43	4.31
Auslese	107	7.67	94.89	24.27	14.74
Beerenauslese	24	41.41	221.90	127.77	51.51
Eiswein	21	73.62	460.16	153.54	89.44
trockenbeerenauslese	5	223.42	493.87	309.66	106.54
<i>Mainz Trade Fair Sample (wholesale, informed)</i>					
all <sup>a</sup>	1105	2.22	227.51	11.47	23.28
<i>by quality level</i>					
quality wine	198	2.22	23.01	4.74	2.83
Kabinett	342	3.32	9.20	4.96	1.17
Spätlese	408	4.19	27.61	7.53	2.69
Auslese	107	7.16	51.12	16.21	8.22
Beerenauslese	24	31.73	150.82	87.91	32.67
Eiswein	21	23.01	203.99	102.86	48.06
trockenbeerenauslese	5	153.37	227.51	192.74	28.16

Source: Diel and Payne, 1994-2002; Mainzer Weinbörse, 1993-2001.

The fact that we restrict our analysis to wineries that are members in the Association of German Quality Wine Estates (VDP) may be the source of a selection bias. In fact, we assume that VDP wineries are more likely than others to sell their wines to the trade and thus tend to grant higher discounts to wine dealers, i.e., have lower wholesale prices. In our model, we capture this effect by



an appropriate constant term. After all, we are not interested in the size of the difference between wholesale and retail prices but their variation.

*Table 2*  
**Descriptive Statistics of Critical Wine Points**

	n	minimum points	maximum points	mean points	standard deviation
all <sup>a</sup>	1015	75	98	86.17	3.35
by quality level					
<i>quality wine</i>	167	75	90	83.29	2.59
<i>Kabinett</i>	312	78	90	85.00	2.37
<i>Spätlese</i>	388	78	93	86.79	2.58
<i>Auslese</i>	98	81	94	88.95	2.54
<i>Beerenauslese</i>	24	86	95	92.13	2.54
<i>Eiswein</i>	21	85	96	92.52	3.16
<i>trockenbeerenauslese</i>	5	93	98	96.80	2.17

Source: Diel and Payne, 1994-2002

Quality in a wine is multi-dimensional and difficult to measure.<sup>7</sup> We refer to two different measures. First, all German wines are assigned a legal quality level according to the sugar content of the grapes they are made from. The grape juice sweetness is measured on the Oechsle<sup>8</sup> scale and in ascending order we distinguish the following quality classifications: *quality wine*, *kabinett*, *spätlese*, *auslese*, *beerenauslese*, *eiswein* and *trockenbeerenauslese* (*tba*). For all these categories, except for quality wine, it is illegal to add any additional sugar (chaptalisation). The quality category of each wine is displayed on the label and reported in both the Gault Millau and the Mainz Wine Trade Fair guide. Since wine quality is determined by weather, vineyard characteristics (Ashenfelter and Storchmann, 2010) and the skills of the winemaker, we assume that both quality

<sup>7</sup> Some authors distinguish between a vertical and a horizontal quality dimension. While the first refers to the quality of the good, the latter denotes the respective idiosyncratic consumer's taste at each vertical quality level (e.g., Tirole, 1988). In this analysis, we only refer to the vertical quality dimension.

<sup>8</sup> Degrees Oechsle (°Oe) is used in Germany and Switzerland and denotes the specific weight of the must compared to the weight of water at a temperature of 20°C, while much of the English speaking world uses a measure called brix. One liter of water weighs 1000g, which equals zero degrees Oechsle. Accordingly, grape must with a mass of 1084 grams per liter has 84 °Oe. Since the mass difference between equivalent volumes of must and water is almost entirely due to the dissolved sugar in the must, degrees Oechsle measures the relative sweetness of the grape juice. Approximately, one brix is equal to one degree Oechsle divided by 4.35 (Peynaud, 1984).

measures are exogenous, i.e., neither is a function of price levels<sup>9</sup> nor of price differences between wholesale and retail prices.

Our second measure of quality is critical points given by wine experts. Since it is the most comprehensive guide for German wine, we draw on the Gault Millau wine guide (Diel and Payne, 1994-2002). The Gault Millau guide rates wines on a 100-point scale, of which only the last 30-point-segment is utilized. Accordingly, 70-79 points denote “average wines for daily consumption” and 100 points “a perfect wine that is worth its weight in gold” (Diel and Payne, 1999a).

Due to the fact that Armin Diel, one of the editors of the Gault Millau Guide and a winemaker himself, does not rate his own wines, the point variable comprises only 1015 observations. Table 2 reports selected descriptive statistics of the critical point data.

## 5. Model

Since the size of the quality signal is defined as the difference between the set retail price and the “full information price” we define our dependent variable as the ratio of retail (Gault Millau) price and wholesale (Mainz) price. We are not interested in the fact that the retail price is higher than the wholesale price but in the variation of the percentage price difference dependent on wine quality and buyers’ information level. The basic equation of interest is therefore

$$(1) \quad \frac{p\_gault_i}{p\_mainz_i} = \beta_0 + \beta_1 Q_i + \beta_2 I_i + \sum aX_i + \varepsilon_i$$

where  $p\_gault_i$  denotes the retail price of wine  $i$ ,  $p\_mainz_i$  the wholesale price of wine  $i$ ,  $Q_i$  its quality and  $I_i$  the information level of the person buying wine  $i$ . The retail-wholesale price ratio is affected by variables other than quality and information level. The vector  $X_i$  stands for those variables. For instance, one winemaker may prefer to sell directly to end consumers and does not grant large discounts to the wine trade. Another winemaker may not want to be involved in retailing his wine and sells mainly to intermediaries at substantial discounts. We capture these effects with firm specific dummy variables. In addition and in contrast to the theoretical signaling literature, we do not consider different firm types (‘high quality’ and ‘low quality’) but different wine types. Each firm offers a broad spectrum of quality. However, independent of the quality of a particular

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<sup>9</sup> Even if one considers price levels to be endogenous in the long run (e.g., high wine prices attract high-skilled wine makers, who improve quality) our dependent variable, the exogeneity assumption for our dependent variable, the difference between retail and wholesale prices, still holds.

wine each winery draws on its respective quality reputation (e.g., Shapiro, 1983). Firm dummy variables account for these differences provided that firm-specific reputation is time-invariant in our sample.<sup>10</sup> Similar effects may be associated with the winegrowing region, the grape variety or the vintage. We control for these effects by including appropriate dummy variables. The error term,  $\varepsilon_i$ , is normally distributed.

While we assume that wholesale prices are very close to the full information level, we are *a priori* uncertain about the information level of retail customers. Assumingly, the group of retail wine shoppers is comparatively heterogeneous. While most consumers are uninformed, there are certainly some well informed wine connoisseurs within this group. For the uninformed to procure information is costly. One has to buy some critical wine reviews and read them or, even better in order to capture the horizontal idiosyncratic quality dimension, buy selected wines and taste them before buying more of it.

Theoretically, consumers will search for or sample wines up to the point where the marginal benefits and marginal cost of the search are equal. Two different models have been developed to rationalize the search process. On the one hand, the search process can be sequential, i.e., consumers search a sample of wines one by one and incur an incremental cost with each additional unit (e.g., Stigler, 1961; Rothschild, 1974, Stahl, 1989; McAfee, 1995). On the other hand, consumers can access information by consulting an “information clearing house” such as an internet price comparison site or a newspaper resulting in sample search cost that is almost fixed (e.g., Salop and Stiglitz, 1977; Varian, 1980; Baye and Morgan, 2001). It is a typical feature of “clearinghouse models” that a subset of consumer gain access to the clearinghouse and become informed while others do not.<sup>11</sup> Since the Gault Millau Wine Guide functions as an information clearinghouse we follow the latter model. Gaining access to the entire price and quality list of all high-end wines is essentially associated with a fixed cost. Thus, the incentive of becoming informed is a function of the “cost of being uninformed.”

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<sup>10</sup> The Gault Millau guide measures the overall quality (reputation) of a wine estate by granting “grapes” that vary from one (“reliable producers”) to five (“the world’s finest”). Since most of the wineries in our sample remain in the same reputation bracket the use of this variable would have substantially reduced our sample size. We therefore did not follow this path and, instead, rely on fixed producer dummy variables to capture reputational effects.

<sup>11</sup> Consumers may decide not to access the clearinghouse because they are loyal to a certain firm (Rosenthal, 1980) or have different access costs (Salop and Stiglitz, 1977; Varian, 1980). Both assume that firms can advertise their prices at the clearinghouse at no cost. In contrast, Baye and Morgan (2001) describe the clearinghouse as an economic agent that maximizes profits by endogenously choosing listing fees from firms and subscription fees from consumers.

*Table 3*  
**Wine Price and Quality Variation**

price range in real €	(1) n	(2) minimum points	(3) maximum points	(4) mean points	(5) standard deviation
0<p≤ 20	884	75	93	85.6	2.86
20<p≤ 40	68	82	94	88.6	2.76
40<p≤ 60	12	87	93	90.6	2.22
60<p≤ 80	8	88	93	90.6	1.99
80<p≤ 100	7	87	95	92.0	2.82
100<p ≤ 200	23	86	96	92.7	2.99
p≥ 200	13	89	98	94.3	3.17

Source: Diel and Payne, 1994-2002

Table 3 reports selected wine quality statistics for different price brackets. Unsurprisingly, expected wine quality, measured as the mean value of critical points, is a function of the wine's price. However the marginal effect of price on quality is not linear but decreasing. In fact, a simple linear-logarithmic function

$$(2) \text{ PTS}_i = \beta_0 + \beta_1 \ln(p\_gault_i) + \sum aX_i + \varepsilon_i$$

where *PTS* stands for critical points, *p\_gault* for the retail price and *X* denotes a vector of control variables, yields a value of 2.4 for  $\beta_1$  (significant at the 0.01% level). That is, the marginal effect of the last Euro spent on a €10 wine is 0.24 quality points whereas the same effect for a €150 wine is only 0.016 points. In other words, one quality point for the €10 wine equals a value of €4.16 while a quality point for a €150 wine is worth €62.50<sup>12</sup>

In column (5) of Table 3, we also report the quality dispersion, i.e., the quality standard deviation, within each price bracket. Accordingly, for the uninformed buyer the risk of failure, i.e., the chance of picking a wine that has a lower than average quality, appears to be the highest at the lower and the higher end of the price spectrum. However, and even with identical standard deviations, when multiplied by the financial value per lost quality point, as shown above, the monetary risk of being uninformed grows exponentially with the wine's price. That is, the greater the monetary investment, the more consumers are willing to pay for information as an insurance against negative quality surprises (see also Costanigro et al., 2009). Given the fixed-cost character of information collection, the incentive of

<sup>12</sup> We calculated this as  $\frac{1}{\beta_1 / p\_gault}$  for  $\beta_1 = 2.4$ .

being informed is assumed to be a positive function of the wine price. We therefore assume that the retail price ideally proxies the degree of consumer information, i.e., the fraction of informed buyers.

Inserting the retail price ( $p_{\text{gault}}$ ) for  $I_i$  into equation (1), however, is problematic because the same covariate is already part of the dependent variable. A simple Hausman test confirms the endogeneity problem at the 0.1% level. We thus have to find an instrument for the retail price that is uncorrelated with the price ratio.

Following the work by Ashenfelter and collaborators (Ashenfelter et al., 1995; Ashenfelter, 2008; Ashenfelter and Storchmann, 2010), we chose to instrument the retail price by employing a hedonic price function that essentially relies on three weather variables: rainfall in the winter preceding the growing season, rainfall during the harvest, and growing season temperatures. Given the small area covered,<sup>13</sup> we assume that each wine is affected by weather changes in the same way (see also Ashenfelter 2008; Ashenfelter and Storchmann, 2010).

We augment this function with a variable denoting the age of the wine and dummy variables for the respective quality levels (*kabinett*, *spätlese* etc.), the wine's character (dry, sweet) and the region of origin (Mosel, Rheingau). Table 4 reports these first-stage estimates.

Denoting the instrumented retail price variable  $\hat{I}$  we obtain our final model

$$(3) \quad \frac{p_{\text{gault}_i}}{p_{\text{mainz}_i}} = \beta_0 + \beta_1 Q_i + \beta_2 \hat{I}_i + \sum aX_i + u_i .$$

According to BR, we expect the price signal ( $p_{\text{gault}}/p_{\text{mainz}}$ ) to be positively associated with quality and negatively with the fraction of informed consumers, i.e., we expect  $\beta_1$  to be positive and  $\beta_2$  to be negative.

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<sup>13</sup> The Rheingau region and the vineyards of the Rhine tributaries Mosel and Nahe river lie within an area of about 60 by 40 miles, which equals an area covered by Napa and Sonoma county together.

*Table 4*  
**First Stage Instrumental Variable Regression**  
 Dependent Variable  $\ln(\text{Retail Price})$

Constant	4.544 (16.95)
Avg. Temperature Spring <sup>a</sup>	-0.004 (-1.50)
Avg. Temperature Ripening Period <sup>b</sup>	0.008*** (8.45)
Rain Winter <sup>c</sup>	-0.001*** (-3.25)
Rain Ripening Period <sup>d</sup>	0.001*** (2.98)
R <sup>2</sup>	0.900
adj. R <sup>2</sup>	0.894
SSE	65.69
F statistic	159.27
N	1106

Heteroskedasticity-consistent t-values in parentheses. Significance level 1% (\*\*\*), 2%(\*\*) and 5% (\*).

<sup>a</sup> March to July in degree Celsius; <sup>b</sup> August to October in degree Celsius; <sup>c</sup> December to March in ml,

<sup>d</sup> June to October in ml; Although not shown here, the equation contains dummy variables for style, grape variety, region and a full set of producer fixed effects.

## 6. Results

### 6.1 Price-Quality Correlations and Price Dispersion

Before turning to the results of the model described above, we display quality-price correlations for each of the two data sets differentiated by price segments (Figure 1). In the price segment below \$100 per bottle both data sets show almost identically low correlations ranging between 0.3 and 0.4. However, for the price brackets of \$150 and above, the wholesale price-quality correlation increases dramatically up to 0.7. In contrast, the retail price-quality correlation drops to minus -0.4 and then increases to 0.1 for higher priced wines.

*Figure 1*  
**Price-Quality Correlations by Sample and Price Bracket**



	<€50	€50-99	€100-149	€150-199	>€199
Wholesale Prices					
$r(p,q)$	0.313**	0.312*	0.260 <sup>+</sup>	0.473	0.678
(n)	(1518)	(23)	(10)	(8)	(3)
Retail Prices					
$r(p,q)$	0.435**	0.294 <sup>+</sup>	-0.417 <sup>+</sup>	-0.105	0.153
(n)	(1028)	(17)	(17)	(6)	(13)

Significance 1% (\*\*), 5% (\*), 10% (<sup>+</sup>),  $r(p,q)$  price-quality correlation coefficient.

Although not all correlation coefficients are statistically significant, we suspect that the U-shape of both curves results from two different forces. First, if higher quality wines are more expensive than lower quality wines and signaling is more common for high quality wines we should see falling price-quality correlations with increasing price. This is reflected by the falling branch of the curves. Second, if consumers' information levels are mirrored by the wine price we should see price-quality correlations that increase with the wine price. This is

reflected in the upward sloping part of the curves. The latter effect finds further support by the high price-quality correlation for high priced wines in the wholesale sample (with assumingly well informed buyers). We will refer to the model described in equation (2) to decompose these effects.

## 6.2 Signaling When Quality is Measured by Oechsle Degrees

Table 5 reports IV and OLS results of the model described in equation (2) when quality refers to the Oechsle-based categories *quality wine*, *kabinett*, *spätlese* etc. Although both models exhibit the same signs for all variables, the OLS results are less significant and consistently lower in value. In addition, for the information variable, the difference between OLS and IV estimates becomes larger as we restrict the sample to lower price brackets. This reflects the fact that the relation between retail-wholesale price ratio on the one hand and retail price on the other hand, and thus the endogeneity bias, becomes more pronounced for less expensive wines. The following, therefore, only refers to the IV results.

As expected, the price signal is negatively correlated with the fraction of informed buyers. Independent of the price bracket, the information-proxy exhibits a significance level that is consistently below the 2% level. By removing the most expensive wines from the sample, i.e., by moving from column (1) towards column (4), the coefficients as well as their statistical significance grow considerably suggesting that the price signal quickly disappears as buyers become better informed. For instance, the coefficient (and constant elasticity) of -0.206 in column (1) indicates that a retail price increase of €1 and the resulting increase in the number of informed buyers lowers ( $p\_gault/p\_mainz$ ) by 1.2% at the mean retail price of the sample. This information effect gets substantially stronger as we only consider lower priced wines.

We also find a positive relation between signal size and wine quality. Starting with the lowest category *quality wine* the coefficients consistently grow with quality<sup>14</sup>. This is true for all price segments. The effect becomes more significant when we consider only lower priced wines. However, since there is no *beerenauslese* and *trockenbeerenauslese* below €15 we omit two of seven quality categories.<sup>15</sup>

<sup>14</sup> Note that all coefficients are relative to the reference category *eiswein*.

<sup>15</sup> These results are stable across different specifications. For instance, a log-linear model yields almost identical significance levels. However, for the sake of brevity and ease of interpretation of marginal effects we do not report them here (note that for log-linear estimates the coefficients roughly equal percentage changes of the percentage surcharge).



*Table 5*  
**Model Results Using Degree Oechsle Categories**

	dependent variable (retail price/wholesale price) for real retail price segment <sup>a</sup>							
	(1)		(2)		(3)		(4)	
	all		< €100		< €50		< €20	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
information level <sup>b</sup>	-0.109 (-1.43)	-0.206* (-1.75)	-0.138 <sup>+</sup> (-1.71)	-0.367*** (-2.73)	-0.064 (-1.46)	-0.351*** (-3.07)	-0.061 (-1.37)	-0.523*** (-4.11)
quality wine	-0.368 (-1.47)	-0.651* (-1.77)	-0.604 (-1.60)	-1.273** (-2.42)	-0.298** (-2.47)	-1.104*** (-3.40)	-0.040 (-0.67)	-0.604*** (-3.88)
kabinett	-0.389* (-1.62)	-0.653* (-1.86)	-0.622 (-1.69)	-1.253** (-2.47)	-0.330*** (-2.81)	-1.094*** (-3.52)	-0.063 (-1.17)	-0.560*** (-3.99)
spätlese	-0.305 (-1.44)	-0.528* (-1.74)	-0.526 (-1.53)	-1.061** (-2.31)	-0.264*** (-2.67)	-0.908*** (-3.48)	-0.014 (-0.36)	-0.319*** (-3.58)
auslese	-0.120 (-0.71)	-0.273 (-1.23)	-0.322 (-1.05)	-0.693* (-1.85)	-0.126 <sup>+</sup> (-1.70)	-0.570*** (-3.33)		
beerenauslese	-0.039 (-0.40)	-0.040 (-0.40)	-0.277 (-1.02)	-0.283 (-1.03)				
trockenbeeren- auslese	0.238 (1.01)	0.343 (1.40)						
R2	0.317	0.317	0.320	0.324	0.311	0.319	0.427	0.446
adj. R2	0.272	0.272	0.275	0.279	0.265	0.273	0.386	0.406
SSE	50.39	50.37	47.23	46.95	39.79	39.37	17.23	16.66
F statistic	7.06	7.08	7.03	7.16	6.74	6.97	10.41	11.24
N	1105	1105	1068	1068	1051	1051	973	973

Heteroskedasticity-consistent t-values in parentheses. Significance level 1% (\*\*\*), 2%(\*\*) and 5% (\*). <sup>a</sup> in € per 0.75l bottle. <sup>b</sup> proxied by the natural logarithm of the real retail price; for IV this is instrumented with weather variables. All quality categories are relative to *eiswein*. Although not shown here, all equations contain a constant term, dummy variables for style, grape variety, region and a full set of producer fixed effects.

*Table 6*  
**Model Results Using Critical Points**

	dependent variable (retail price/wholesale price) for real retail price segment <sup>a</sup>							
	(1)		(2)		(3)		(4)	
	all		< €100		< €50		< €20	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
information level <sup>b</sup>	-0.096 (-1.32)	-0.162 (-1.47)	-0.137 <sup>+</sup> (-1.71)	-0.359*** (-2.67)	-0.067 (-1.51)	-0.365*** (-3.09)	-0.060 (-1.41)	-0.509*** (-4.08)
quality wine	0.005 (1.46)	0.008 (1.58)	0.010* (2.05)	0.016** (2.55)	0.007* (2.19)	0.015*** (3.23)	0.006** (2.44)	0.011*** (3.85)
kabinett	-0.003 (-1.31)	-0.006 (-1.54)	-0.006 (-1.51)	-0.013** (-2.36)	-0.004** (-2.56)	-0.013*** (-3.52)	-0.000 (-0.27)	-0.006*** (-3.69)
spätlese	-0.003 (-1.46)	-0.006* (-1.63)	-0.006 (-1.60)	-0.013* (-2.39)	-0.004*** (-2.89)	-0.013*** (-3.62)	-0.000 (-0.74)	-0.006*** (-3.77)
auslese	-0.003 (-1.26)	-0.004 (-1.49)	-0.005 (-1.43)	-0.011* (-2.23)	-0.003*** (-2.79)	-0.011*** (-3.59)	-0.000 (-0.05)	-0.003*** (-3.30)
beerenauslese	-0.001 (-0.39)	-0.002 (-0.85)	-0.003 (-0.90)	-0.007 <sup>+</sup> (-1.95)	-0.002 <sup>+</sup> (-1.82)	-0.007*** (-3.50)		
trockenbeeren- auslese	-0.000 (-0.27)	-0.000 (-0.26)	-0.003 (-0.94)	-0.003 (-0.93)				
	0.002 (0.90)	0.003 (1.12)						
R <sup>2</sup>								
adj. R <sup>2</sup>	0.313	0.313	0.318	0.322	0.310	0.318	0.437	0.457
SSE	0.264	0.264	0.269	0.273	0.260	0.268	0.394	0.414
F statistic	48.76	48.77	45.51	45.24	38.07	37.62	15.63	15.11
N	6.42	6.41	6.43	6.55	6.17	6.41	9.96	10.75

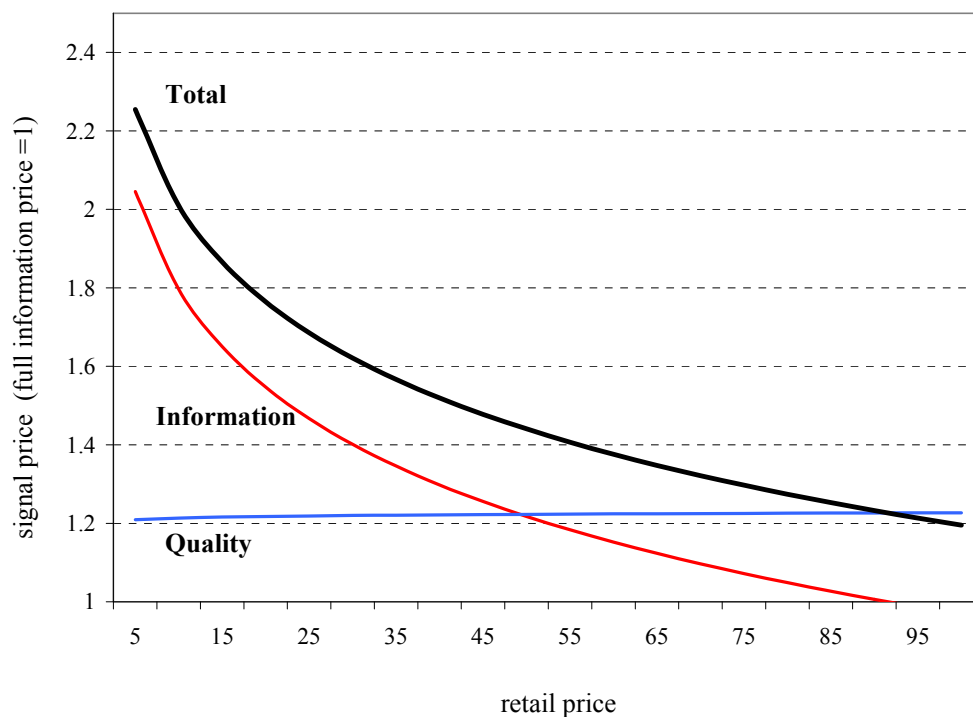
Heteroskedasticity-consistent t-values in parentheses. Significance level 1% (\*\*\*), 2%(\*\*) and 5% (\*). <sup>a</sup> in € per 0.75l bottle. <sup>b</sup> proxied by the natural logarithm of the real retail price; for IV this is instrumented with weather variables. All quality categories are relative to *eiswein*. Although not shown here, all equations contain a constant term, dummy variables for style, grape variety, region and a full set of producer fixed effects.

### 6.3 Signaling When Quality is Measured by Experts' Critical Points

When we change the quality variable and refer to expert ratings instead of degrees Oechsle categories we obtain very similar results (Table 6). Again, as already seen in Table 5, all OLS estimates exhibit a serious bias towards zero.

Table 6 reports almost identical coefficients for the information variable in all price segments. Similarly, the quality variable yields significant results that also increase with the price level. In addition to the general critical point variable, we also introduced slope shifters for each legal quality (degree Oechsle) category. As expected, the coefficients suggest that the marginal effect of one critical point on the price signal is an increasing function of the quality categories. For instance, referring to the entire sample (column 1), while the marginal effect of critical points for *quality wine* is 0.002, that one of *trockenbeerenauslese (tba)* is 0.011 (with 0.008 for *eiswein* as reference).

Figure 2  
Quality and Information Effect on the Price Signal of *Spätlese* Wines



Given that both the fraction of informed customers as well as wine quality are positive functions of the price and have opposite effects on the size of the price signal, i.e., the ratio of retail over wholesale price, we are now interested in

the strength of the combined effects. In order to express both variables along the price axis we need to convert critical points into prices.<sup>16</sup> Figure 2 shows the effect of each of these variables as well their combined impact on the price signal for wines under EUR 100 in the *spätlese* category drawing on the estimates reported in Table 6, Column 2. Here, the retail/wholesale price ratio is shown as a function of the retail price. We, therefore, converted critical points into prices using equation 2 (with the results given in footnote 16).

The curve denoted “Quality” shows the isolated effect of increasing quality on prices. The surcharge over the full information price rises from 21% to 23%. In contrast, the curve denoted “Information” depicts the impact of a higher information level (also expressed in terms of prices) on the price. Rising information yields substantial price discounts. While the surcharge over the full information price within the under EUR 10 range is about 100% it falls to zero at EUR 95. That is, the information effect by far dominates the quality effect. Both effects combined exhibit a decline in the ratio retail price over wholesale price surcharge from 2.25 to 1.20. Quality and information effects are similar in the remaining wine categories.

## 7. Summary

In this paper, we analyze if and to what extent prices can signal product quality. We empirically examine the following hypothesis first published by Bagwell and Riordan (1991). High quality producers distinguish themselves from low quality producers by charging a price above the full information equilibrium. This may convince uninformed buyers but will deter informed ones. As a result, the price signal decreases as the market learns about the “true quality” and the fraction of uninformed consumers declines.

We refer to two price samples of identical wines and analyze the difference between both. The first sample consists of prices for assumingly informed wholesalers and restaurateurs who professionally deal with wines. These prices are set by the wine producer at an annual wholesaler wine fair where each wine can be tasted. The second sample comprises retail prices for the imperfectly informed public.

Referring to critical wine points as quality measure and retail prices as information proxy we find support for the Bagwell-Riordan model. Price signals respond positively to wine quality and negatively to increasing information. We show that the information effect by far dominates the quality effect. Overall, the

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<sup>16</sup> Equation (2), run for *spätlese* wines only, yields a  $\beta_1$  of 79.88 and a  $\beta_2$  of 2.37 (both significant at the 0.01% level).

surcharge over the full information price declines dramatically as the price level -- and with it the information level of consumers -- increases.

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