Prices of American Pinot Noir Wines: Climate, Craftsmanship, Critics

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Abstract

Pinot Noir, a variety originating from Burgundy in France, is the most expensive category of table wine produced in North America. This paper is aimed at analyzing its price determinants and is focusing on climate, critical scores, and variables related to the winemaker. The main findings are: (1) Pinot Noir prices are mainly determined by temperature and precipitation. General temperature increases are not beneficial. In fact, the optimal climate is similar to that one in Burgundy. (2) The second most important variable is the winemaker. His or her skill and reputation have a significant impact on prices. (3) Expert knowledge, in the form of critical scores, has only little explanatory value.

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Abstract
Pinot Noir, a variety originating from Burgundy in France, is the most expensive category of table wine produced in North America. This paper is aimed at analyzing its price determinants and is focusing on climate, critical scores, and variables related to the winemaker. The main findings are: (1) Pinot Noir prices are mainly determined by temperature and precipitation. General temperature increases are not beneficial. In fact, the optimal climate is similar to that one in Burgundy. (2) The second most important variable is the winemaker himself. His or her skill and reputation have a significant impact on prices. (3) Expert knowledge, in the form of critical scores, has only little explanatory value.

1 Introduction

By many metrics -- including tons harvested, price per ton and average list price per bottle of finished wine -- the 1990's have been witness to an astonishing revival of interest in American pinot noir. With about 9.160 hectares bearing in 2004 Pinot Noir has only a 5.1% share of California's total wine grape acreage (see Table 1). In terms of area planted and value of crushed grapes, however, it is already the fourth most important red wine grape variety in the state -- after Cabernet Sauvignon, Zinfandel, and Merlot. Furthermore, recent growth rates in Pinot acreages are significantly above average. From 2000 to 2004 alone, the planted area had increased by about 95% -- more than for any other grape. In Oregon, Pinot Noir is the most widely planted of all varieties – red or white – accounting for 56% of wine grape acreage.

Pinot Noir is characterized by a very low crop yield per acre. In California in 2004, only 7.65 tons of grapes per hectare were crushed. Given crop yields of more than 12 tons per hectare for Cabernet Sauvignon, 18 tons per hectare for Merlot and 35 tons per acre for Rubired, Pinot Noir's low specific yield is second to none. In Oregon, the yield per harvested hectare of Pinot Noir was less than six tons in 2004.

The low crop yield of Pinot Noir is offset by the very high prices for crushed grapes. In fact, California and Oregon pinot noir has quietly emerged as the single most expensive category of ultra-premium table wine produced in North America. There are many reasons for this realignment. One is the virtual non-existence of inexpensive pinot fruit, owing largely to the impossibility of growing it successfully in the warm, low-cost, high-volume regions of California's Central Valley. The absence of inexpensive fruit pushes the average price per ton of Pinot Noir far higher than the equivalent average price for Cabernet Sauvignon or Merlot. In 2004 the California statewide average price for crushed pinot noir was $1620 per ton, as against just $978 for Cabernet Sauvignon, $799 for Merlot, and $474 for Zinfandel (CASS, 2005a).[1] In Oregon, the average price per ton was $2090 in 2004 (U.S. Department of Agriculture, 2005). As a result, Pinot Noir revenue per hectare -- despite its low crop yield -- is surpassed only by Merlot. Hence, the incentive to expand the Pinot Noir acreage appears to be strong.

However, not all pinot noir wines are expensive. In fact, prices can vary widely. For instance, all pinot noir wines reviewed in the wine magazine *Wine Spectator* between 1998 and 2003 range from $7 to about $90 per bottle. What determines the prices of pinot noir wines? On the one hand one might suspect that exogenous factors such as climatic conditions and characteristics of the vineyard are crucial quality and therefore price determinants. These factors are often subsumed under the French enological term *terroir.* On the other hand, and this is typically stressed by New World producers, technological advances and improved viticultural practices have enabled winemakers to offset unfavorable weather conditions. Frank Prial, wine columnist for the *New York Times*, has gone so far as to argue that the vintage chart is dead: "Rarely does a year go by that doesn't produce good wine … the winemakers of the world have rendered the vintage chart obsolete" (Prial, 2000). Experiments have shown that wine drinkers cannot distinguish in blind wine tastings the wines of years rated high from those of years rated low (Weil, 2001).

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[1] Only exotic varieties with a tiny production crushed, such as Nebbiolo (260.9 t crushed, $2553/t), Melon (11.1 t crushed, $2170/t), Arneis (70.5 t crushed, $2078/t), Aleatico (35.9 t crushed, $1985/t), Flora (39 t crushed, $1950/t), Vernaccia (51 t crushed, $1807/t), and Roussanne (818 t crushed, $1775/t), attained higher prices. Together they total to less than 0.2% of the Pinot Noir production (CASS, 2005a).

Given these opposing opinions, many wine consumers resort to expert knowledge in the form of scores or points awarded to individual wines by critics, of which Robert M. Parker, Jr., and the magazine *Wine Spectator* are the best known and most widely cited. Many wineries and consumers complain about the strong influence of critical scores on wine prices, but, the empirical evidence is equivocal. While some studies found a significant influence of wine scores on Bordeaux wine prices (e.g., Jones and Storchmann, 2001), others found only little evidence (e.g., Ashenfelter and Storchmann, 2003).

This paper is aimed at shedding some light on the determinants of prices of Pinot Noir wines from California and Oregon. The analysis draws on a panel data set of 451 wines described below. After presenting the model and the data in Section 2, Section 3 will give the main empirical results. The paper will end with a summary and an outlook (Section 4).

2 Model and Data

This paper is aimed at explaining suggested retail prices of Pinot Noir wines from California and Oregon employing a hedonic price analysis as introduced by Griliches (1961) and Rosen (1974). We are drawing on a sample of 451 wines reviewed in several issues of *Wine Spectator* between 1998 and 2003 (Wine Spectator, 1998-2003). All prices are nominal and given at the time of review. As shown in Table 2, the range of prices - from \$6 and \$81 per bottle, is comparatively wide.

Although the data have two time-related components, (1) the time of review and (2) the age of the wine at that time, the model has only a cross-sectional structure. We don't analyze the price development of a particular wine over time. In fact, each of the 451 data points represents an individual wine.

The prices of wines reviewed in 1998 and in 2003 are not directly comparable. Due to inflation nominal wine prices are assumed to increase over time. The model captures inflationary effects by introducing a time dependent variable (*t*). The variable increases in integers and is set equal to one in 1998, the first considered year of review, and to six in 2003, the last year considered. Hence, the price of a wine *i* reviewed at time *t* can be expressed as

$$(1)\ \log(P_i) = \alpha_0 + \alpha_1 t_i + \varepsilon_i \ ,$$

where ε_i represents the stochastic error term with the expected value $E(\varepsilon_i)=0$. The parameter α_1 is expected to be positive, denoting nominal price increases over time.

The second time-related variable is the age of the wine at when it was reviewed. Most of the wines were reviewed two years after the vintage. Some wineries, however, release later than others, so quite a few wines were reviewed at age three or four. Most age-worthy wines increase in value as they grow older, but most table wines do not. The overall effect, therefore, is unclear. Thus we extend equation (1) to:

$$(2)\ \log(P_i) = \alpha_0 + \alpha_1 t_i + \alpha_2 age_i + \varepsilon_i \ .$$

It is commonplace to assert that Pinot Noir, along with Riesling, is the most profoundly site-marked of wine grape varieties (Haeger, 2004). This view has its origins in Burgundy, of course, where it is enshrined in France's most granular appellation-based decoupage[2]. If every grape in Burgundy were harvested by the vine's owner, if every owner bottled his own wine, and if every wine were labeled for the most specific geographic designation to which it is entitled – none of which is the case – there would be less than one case of finished wine made per proprietor per vineyard. As North American vintners have become more site-conscious in the last two decades, they too have begun to celebrate *terroir*, and to eschew blending in favor of a proliferation of small and typically vineyard-designated bottlings. So-called "reserve" programs, always

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[2] Burgundy is famous for a huge proliferation of tiny appellations. More than 1000 site names are recognized within the territory that produces the Cote d'Or's two dozen village vines (Haeger, 2004).

meaningless but usually denoting some kind of barrel-selection protocol, have all but disappeared, and coined proprietary names (e.g., Testarossa's Cuvée Niclaire) are decreasingly common (Haeger, 2004). Instead, many top producers like Oregon's Ken Wright and California's Siduri have built their reputations on vineyard-designation. Typically, these producers offer small quantities of many different wines to the marketplace, rather than propose larger quantities of regional blends. With increasing frequency, large producers have mimicked this behavior, settling aside two, four or eight barrels for a special vineyard-designated release. Before examining the economic underpinnings of this behavior, it is fair to observe that the North American practice is only a pale reflection of its Burgundian inspiration. Vineyard nomenclature in North American is not controlled by law – apart from certain regulations on use of the term "estate," so vineyards can be defined in the eye of the vintner. Named vineyards can be large coherent parcels like the nine-hundred acre Bien Nacido Vineyard in California's Santa Maria Valley, or large and discontinuous holdings like the so-called Dutton Ranch in the Russian River Valley. Dutton Ranch would be better expressed as the Dutton Ranches; it is simply a collection of unrelated vineyard parcels with a common owner. Even the famous Hirsch Vineyard on the Sonoma Coast is an array of non-contiguous vine blocks that, according to many winemakers, are so different that they are best viewed as separate vineyards. Conversely, Calera Wine Company vinifies four adjacent parcels as separate vineyards, even though most producers would classify them as blocks of the same vineyard. Nothing prevents producers from inventing vineyard names, or from using what appear to be vineyard names for what are in fact barrel selections of wine.

The commercialization of wine under a designated vineyard label may be aimed at providing more information about the origin of the wine and honoring the *terroir*, but it may also be intended to portray the wine as limited in quantity and exclusive. Additionally, a vintner who holds some wine aside for vineyard designation usually has less base wine available for blending. In any of these cases, the vineyard-designated wine may command a higher market price. In order to capture the possible impact of geo-specific labeling on the suggested retail price we introduced a dummy variable "designated vineyard" (*dv*). It takes on the value of one for a site-designated wine and zero otherwise. The information was taken from the *Wine Spectator* (1998-2004).

Vineyard-designated wines usually are, in fact, produced in relatively small quantities, because the supply of these wines is finite. Thus, the average amount of wine produced for designated vineyards is 899 cases, compared to 3334 cases for all vineyards (see Table 2). However, the correlation between the designated vineyard variable and production is, with r=–0.239, rather small and -- as will be shown later -- the designated vineyard variable does not cause any multicollinearity problems.

Another supply side variable is the quantity produced, also provided by the *Wine Spectator* (1998-2004). In our sample the quantity produced ranges from only 25 cases to 100,000 cases (Table 2). Since we assume that keeping supply short will lead to increasing prices we suspect a negative correlation between quantity produced and price. The model takes the production into account by introducing a production variable (*prod*).

Thus equation 2 can be extended to

$$(3)\ \log(P_i) = \alpha_0 + \alpha_1 t_i + \alpha_2 age_i + \alpha_3 dv_i + \alpha_4 \log(prod_i) + \varepsilon_i$$

It is well known that the quality of any fruit, in general, depends on the weather during its growing season. What is true for fruit is also true for wine. Several studies have examined the relationship between weather and wine prices (e.g., Ashenfelter et al., 1995; Ashenfelter and Byron, 1995, Ashenfelter and Corsi, 2001, Jones and Storchmann, 2001).[3] Most of these involve European wine regions and point to a correlation between warm, dry growing seasons and sufficient rainfall in the preceding dormant period on the one hand, and good quality and high prices on the other. "Great vintages for Bordeaux wines correspond to the years in which August and September are dry, the growing season is warm, and the previous winter has been wet" (Ashenfelter et al., 1995). Except

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[3] Nemani et al. (2001) and Jones et al. (2004) analyze the relationship between climate change (global warming) and wine ratings.

for Ashenfelter and Byron (1995), all of the above models estimated linear relationships between weather data and wine prices.

Table 3 gives the average maximum temperatures for Pinot Noir growing regions in Europe and in the U.S. At first glance, weather station data suggest that all European regions have significantly lower growing season temperatures than the vineyards in Oregon and California. Whereas in Burgundy, the cradle of the Pinot Noir grape, average maximum growing season temperatures are about 22^0C, this is 23.2^0C in Salem/Oregon, 26.2^0C in Napa, and even 30.3^0C in Paso Robles in Southern California. When only looked at the temperature during the ripening period between July and September, this difference becomes even bigger. However, Napa Valley and Paso Robles are not important as Pinot Noir regions; only 2.0% or 0.2%, respectively, of our sample originate from these regions.[4]

Table 2 shows that even within our sample there is a wide range in growing season temperatures from a temperature sum of 123 to about 170^0C. Since differences are due to location as well as to vintage, the lowest value is not necessarily attained in Oregon not the highest in Southern California. In fact, the 123^0C was reached in the Santa Cruz Mountains in 1999, whereas the highest value was reached in Napa Valley in 1997.

However, Pinot Noir is usually an early ripening grape and typically well-suited to cooler areas. Many vintners argue that too much heat burns the fruit, lowers acidity, drives pH too high, and compromises fruity aromas. The hypothesis “warmer is better” may not apply to Pinot Noir in the U.S. In fact, the correlation of price and temperature may be negative or non-linear. Our analysis takes this into account and estimates a linear specification (equation 4a) as well a quadratic relationship between price and temperature (equation 4b). The latter version assumes that increasing temperature improves the grape, but at a decreasing rate. Ultimately, if temperature is higher than a certain optimum, grape quality declines.

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[4] Most wines of our sample come from the Russian River Valley (17.3%), Santa Barbara (15.7%), and Carneros (14.0%). See also Table 5.

In addition, we added two precipitation variables. The first variable accounts for rainfall in the preceding winter (December to March), which was found to be positively correlated with wine prices in Europe in prior studies (e.g., Ashenfelter et al., 1995). As shown in Table 2, the variance of winter rainfalls exceeds temperature variances by far. Thus winter rainfall varies between about 59ml and 1367ml. However, in contrast to European vineyards, especially those in Burgundy, most vineyards in California and some younger vineyards in Oregon are irrigated. Therefore, despite the high variability (see Table 3), we expect the role of winter precipitation to be less important than it is for non-irrigated vineyards. The second precipitation variable denotes rainfall during the late ripening period and the harvest (August and September). The data show that harvest precipitation is unusual in California and in Oregon.[5] It varies between 0ml and 177ml and averages at 14ml. In comparison, the 30-year-average for Dijon/Burgundy is 127ml. We assume a negative correlation between wine prices and precipitation in August and September.

All climate data were taken from the online databases of the California Department of Water Resources (2004) and the Oregon Climate Service (2004). Taking temperature and precipitation variables into account, the extended equation looks as follows:

$$\begin{aligned}\log(P_i) = {} & \alpha_0 + \alpha_1 t_i + \alpha_2 age_i + \alpha_3 dv_i + \alpha_4 \log(prod_i) + \alpha_5 temp_i + \\ & \alpha_7 pr\_wi_i + \alpha_8 pr\_fa_i + \varepsilon_i\end{aligned} \tag{4a}$$

$$\begin{aligned}\log(P_i) = {} & \alpha_0 + \alpha_1 t_i + \alpha_2 age_i + \alpha_3 dv_i + \alpha_4 \log(prod_i) + \alpha_5 temp_i + \alpha_6 temp_i^2 + \\ & \alpha_7 pr\_wi_i + \alpha_8 pr\_fa_i + \varepsilon_i\end{aligned} \tag{4b}$$

Climate variables influence the model in two different ways. First, they differ by year, denoting the quality of the respective vintage. Second, they differ by region denoting the suitability of a particular wine area. However, since data from only 14 relevant climate stations are available (see Table 4), a major problem is that the station may not be in sufficiently close proximity to the vineyard/region it represents, i.e., the macro-climate measured by the climate station and the vineyard-specific meso-climate can be very different. For instance, the wine regions Arroyo Grande Valley, Edna Valley, and Paso Robles are all represented by the climate station #52 in San Luis Obispo. Some vineyards, especially in Paso Robles, may be as far as 30 miles away from this weather station. Hence, local or regional weather data can only be proxy variables for the actual weather in the vineyard and are to be judged with caution.

Temperature and precipitation, however, are not the only relevant climatic variables[6]. For instance, temperature differences between day and night are often considered important quality determinants (e.g., Ashenfelter and Byron, 1995). The biggest climatic differences among the pinot-friendly regions in California and Oregon are associated with diurnal variation, not with overall heat accumulation. Where daytime maxima are high, cold nights are essential to maintain pinot-friendliness. In some regions, especially in Napa Valley, the morning fog is deemed beneficial for viticulture. Further variables may be the direction and force of winds as well as the cloud cover. Also, geological factors differ widely from thin and stony to deep and loamy soils (e.g., Halliday, 1993). In addition, the region is often deemed a collective reputation indicator (e.g., Landon and Smith, 1998). In order to further account for regional effects we will introduce regional dummy variables (*reg*)[7]. In this paper, we distinguish 19 regions: (1) Anderson Valley, (2) Arroyo Grande Valley, (3) Carneros, (4) Edna Valley, (5) Marin County, (6) Mendocino, (7) Monterey, (8) Napa Valley, (9) Paso Robles, (10) Russian River Valley, (11) Santa Barbara, (12) Santa Cruz Mountains, (13) Santa Lucia Highlands, (14) Santa Rita Hills, (15) Sonoma Coast, (16) Sonoma Mountain, (17) Sonoma Valley, (18) Umpqua Valley, and (19) Willamette Valley. In addition, we also introduced a dummy

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[5] It should be mentioned that harvest rainfall has been a problem in Oregon historically. However, this does not affect our sample, which encompasses only the Oregon vintages 1998 and 1999, since all harvest periods since 1997 have been fairly dry.

[6] For an overview of relevant factors see Gladstones (1992).

[7] In addition, regional dummy variables also capture other regional characteristics such as regulaions or land prices.

variable for supra-regional blends. Table 5 reports the descriptive price statistics for each region.

Aside from exogenous environmental factors, wine making involves highly skilled labor. It depends heavily on the knowledge, skill and experience of the wine maker. Hence, we also added dummy variables for each of the 93 producers (*vint*). As a result, equation (4) is extended to

(5)

$$\log(P_i) = \alpha_0 + \alpha_1 t_i + \alpha_2 age_i + \alpha_3 dv_i + \alpha_4 \log(prod_i) + \alpha_5 temp_i + \alpha_6 temp_i^{\,2} + \alpha_7 pr\_wi_i + \alpha_8 pr\_fa_i + \sum_{k=1}^{19} a_k reg_i + \sum_{j=1}^{93} a_j v\mathrm{int}_i + \varepsilon_i$$

In addition, we consider expert knowledge in the form of ratings given to the wines by the *Wine Spectator*. Theoretically, ratings are given at a scale ranging from zero to 100, where 95 to 100 points means “classic”, 90 to 94 “outstanding”, 85 to 89 “very good”, 80 to 84 “good”, 70 to 79 “average”, and below 70 “below average” (Wine Spectator, 2004). In our sample the poorest rating is 70 points, while the highest is 94 points (see Table 2).

Ideally, the score or the points a wine attains should reflect its overall quality and, therefore, contain all publicly available fundamentals plus some insider knowledge not available to laymen. However, the role of expert knowledge and its impact on wine pricing is disputed [8]. While some studies have found a considerable influence of critical points on wine prices (e.g., Jones and Storchmann, 2001), others found that wine prices are more affected by fundamentals (Ashenfelter and Jones, 1999; Ashenfelter and Corsi, 2001; Ashenfelter and Storchmann, 2003).

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[8] The similarity to he stock market is apparent. Advocates of the so-called efficient market theory claim that expert knowledge does not exist (e.g., Malkiel, 2000).

In order to capture the possible effects of critical scores we specify two equations. First, we assume that critical scores (*pts*) reflect all fundamentals and, therefore, express the overall quality (= price) of the wine. Thus, correcting only for inflation, we simply add the point-variable to equation (1) and get

(6) $\log(P_i) = \alpha_0 + \alpha_1 t_i + \beta_1 pts_i + \varepsilon_i$.

In a further equation, we then extend equation (5) by the point-variable in order to see what the inclusion of rating adds to the overall explanation of price variations .

(7)

$$\log(P_i) = \alpha_0 + \alpha_1 t_i + \alpha_2 age_i + \alpha_3 dv_i + \alpha_4 \log(prod_i) + \alpha_5 temp_i + \alpha_6 temp_i^2 + \alpha_7 pr\_wi_i + \alpha_8 pr\_fa_i + \sum_{k=1}^{19} a_k reg_i + \sum_{j=1}^{93} a_j v\mathrm{int}_i + \beta_1 pts_i + \varepsilon_i$$

3 Results

Table 6 shows the results of simple OLS estimates of the basic (dummy variable free) equations mentioned above. As can be inferred from the first column, nominal wine prices increase over time. For the considered time period, the annual increase has been about 10% – well above the growth rate of the consumer price index. Given the extraordinary increase in land prices in California over the last decade this is little surprising. Table 7 shows that vineyard prices in California have increased by about 10% per year between 1992 and 2002.

Also, wines get more expensive as they grow the older – denoted by the significant positive parameter for the age-variable. However, with an R^2 of only 14% equation (2) does not give a sufficient explanation of wine price variations. As expected, wine prices are determined by more than the age of the wine alone.

Column two of Table 6 refers to expert ratings and their capacity to explain the price variability. It shows the results of an estimate of equation (6). Since only the range between 70 and 94 points is used, we got rid of the inherent constant term by subtracting 70. Thus the worst wine obtained zero points while the best one received 24 points. Since the estimate shows evidence of heteroscedasticity, White's (1980) heteroscedasticity correction for the coefficient variances was calculated and the appropriate t-statistics are given in brackets. Although expert ratings appear to be a much better variable than age for explaining American Pinot Noir prices, ratings can only capture one third of the price variability. In addition, the Ramsey RESET test strongly suggests the existence of a specification error in equation (6). Thus, reliance on expert opinion alone appears to be little trustworthy.

In contrast to equation (6), equations (4a) and (4b) rely on fundamentals only. We estimated both equations with and without a constant (columns 3-6)[9]. Since 39 wines of the sample are "supra-regional blends" no regional climate data were available for these wines. Hence, the sample size decreased from n=451 to n=412. All estimates confirm the importance of the time and age variables. In addition, wine prices are negatively correlated with quantity produced: Larger quantities lead to lower prices per bottle - but at a decreasing rate. Since the production was estimated with its logarithm, the estimated parameter α_4 denotes a constant elasticity of about –0.13, i.e., a decrease in quantity by 10% leads to an increase in price by 1.3%. This seems to be a clear indication that – ceteris paribus – dividing production among multiple bottlings is not rewarded by an offsetting price increase and, therefore, does not pay off. Furthermore, the commercialization of Pinot Noir wines under a designated vineyard label has, as expected, a significantly positive influence on wine price. The parameter indicates that the introduction of a vineyard-site label increase prices by about 17%. All of these parameters are relatively constant among the different equations.

As for climatic factors we refer to average maximum temperatures and winter and harvest precipitation only. Factors suggested by Gladstones (1990), such as humidity and the

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[9] Note that the R^2-values are not directly comparable.

difference between maximum and minimum temperatures, did not prove to be significant. In addition, no significance was found for solar radiation, a factor which was identified as crucial for the value of German vineyard sites by Ashenfelter and Storchmann (2001).

The amount of precipitation, a very important factor in European viticulture, turns out to be insignificant in all specifications (Table 6). Drawing on findings for Europe that winter precipitation has a positive and fall precipitation a negative effect on wine quality (e.g., Ashenfelter et al., 1995; Jones and Storchmann, 2001) Table 8 shows that Pinot Noir regions in the U.S. are privileged by any standard. On the one hand, winter precipitation is substantially higher in California and Oregon than it is in Burgundy. Whereas the long-run average for Dijon is 188 mm for the December to March period the values for Salem/Oregon and Napa are 547 mm and 466 mm, respectively. Even in Paso Robles on California's Central Coast the winters, with 256 mm of rainfall, are significantly wetter than Burgundy. In addition, most California vineyards and many younger Oregon vineyards are irrigated. Hence, lack of water is no issue, although the best way to use irrigation is hotly debated.

On the other hand, precipitation during the ripening period and the harvest – a great danger in Europe – plays virtually no role in our sample. The average August/September precipitation of 117 mm in Dijon/France is even higher than the maximum within or sample, which was 107 mm (attained in the Santa Rita Hills in 2001). The 30-year average for Salem/Oregon is 54 mm, for Napa 13 mm, and for Paso Robles 11 mm. The average for the 451-wine sample is 14.2 mm (Table 2).

In contrast, temperature turns out to be very significant. Comparing equation (4a) and (4b) shows that the quadratic version is clearly superior to the linear one - regardless whether or not one includes a constant term. This confirms the assumption that there is no linear but rather a quadratic relationship between temperature during the growing season and Pinot Noir prices. Since the constant term is not significant, equation (4b) as given in column 6 is taken as the reference equation. By taking the partial derivative and setting it equal to zero one can calculate the optimal growing season temperature as

$$(8) \quad \frac{\partial \log(P)}{\partial\, temp} = \alpha_5 + 2\alpha_6 temp = 0 .$$

Thus the sum of the average maximum temperature is at its optimum at 149°C for the entire growing season, which is substantially higher than the 132°C for Dijon in Burgundy. Figure 1 displays growing season temperatures for selected weather stations and years compared to the 149 degree optimum which is depicted by the dashed line. While especially Carneros and the Willamette Valley (McMinnville) deviate relatively little from this optimum, temperatures in Napa Valley (Oakville) and in the Santa Cruz Mountains (Green Valley Road) are consistently too high or too low, respectively.

Furthermore, we find that all Californian weather stations follow more or less the same pattern with a peak in 1997 and a trough in 1998. Only the Oregon weather station in McMinnville (Willamette Valley) displays relatively constant temperatures over time. In addition, the variation among the stations is not only determined by the latitude but also by the distance to the coast. The proximity to the Pacific coast is the main reason for the fact that the Green Valley Road station in the Santa Cruz Mountains as well as San Luis Obispo in Southern California are the coolest weather stations of our sample.

Given distances between representative weather station and vineyard of up to 30 miles and the unknown mesoclimate in the vineyard, the regional weather data appear to be somewhat noisy. Hence we estimated an alternative equation using Carneros weather data only. Since this equation does not include regional variations anymore but variations over time only we can re-include "supra-regional blends" and thus refer to the entire 451 wine sample. The estimate of this equation as given in column 7 of Table 6 shows an improvement over the equations using regional data. The results display a sharp decrease in heteroscedasticity and a significant increase in the goodness to fit (R^2) to 0.524. With slightly different parameters α_5 and α_6, the temperature optimum now drops to 133°C, which is well in the range of temperatures in Burgundy.

Starting from this equation (with Carneros climate data only) and adding dummy variables for regions and wine producers, we get equation (5), which is shown in Table 9. With a goodness to fit of 0.783 and an adjusted R2 of 0.704 equation (5) displays a substantial improvement to equation (4b) indicating that a major part of the price variations is due to regional and personal characteristics. As for the estimated parameters, there is little change compared to the prior equation. Most important, the parameters for the temperature variables confirm the Burgundy benchmark, i.e., the temperature optimum of 133^{o}C. The rainfall variables remain insignificant.

Most of the regional dummy variables are insignificant. However, wines from Carneros and the Russian River Valley are significantly more expensive than others, showing a premium of about 20-25% compared to regional blends for which no dummy variable was included. On the other hand, wines originating from Monterey and Oregon's Umpqua Valley appear to display a discount of more than 30%. How are these findings to be interpreted? On the one hand the parameter can be an indication that wines from Carneros and the Russian River Valley are "better" than other wines and command higher prices *because* they are better. This can be due to mesoclimatic or geological factors that are not accounted for. By the same logic, Monterey and Umpqua Valley wines should be inferior. However, the price data we are using are not market prices as one may obtain from auctions. In fact, our price data are recommended retail prices and, therefore, set by producers. This fact allows for an entirely different interpretation of prices; namely that Carneros and Russian River Valley producers invoke the reputation of their wine regions to charge more for their wines, while Monterey and Umpqua Valley producers are forced to leave their wines in a more affordable bracket because regional reputation will not justify a premium. Whether the prices reflect a difference in quality or a premium based on regional reputation, Carneros and Russian River Valley wines are significantly more expensive than Monterey and Umpqua Valley wines.

The same is true with regard to producers of which only a few are displayed in Table 9. Taking into account all independent variables, a few producers, such as Etude, Saintsbury, Williams Selyem, Signorello, and Cambria – ask prices higher than any of the considered fundamentals would appear to justify. In the case of Etude, produced by the legendary Tony Soter, prices exceed prices of "comparable" wines by more than half. (On the other hand, Pinot Noirs produced by Brophy are priced 47% below the price of "comparable" wines.) The list of high-priced producers is oddly heterogeneous. Etude, Saintsbury and Williams Selyem were all pioneers among California's Pinot producers. Williams Selyem in particular developed an almost iconic reputation for fine Pinot Noir in the 1980's. Signorello is nearly the opposite case. Cambria, different again, is a relatively new label, offering a large volume of wine to market, and choosing to rely heavily on advertising (Haeger, 2004). The model is not designed to explain why these wines are high priced relative to fundamentals, or if the explanation is the same for each case. Winemaking skill could be at work, or brand reputation, or self-promotion. Or the wines could simply be overpriced.

By adding critics' points to equation (5) we get equation (7). However, the OLS estimator will be biased and inconsistent when the explanatory variable "points" is endogenous. In this case 2SLS will be more efficient. Therefore, we applied a test for endogeneity as suggested by Hausman (1978) and further developed by Davidson and MacKinnon (1993): compare OLS and 2SLS estimates and determine whether the differences are statistically significant. First, we estimated an auxiliary equation and regressed the point-variable on all the other exogenous variables plus a set of instrumental variables that are correlated with the "suspect" variable "points (pts)" but not with the error term in the price equation. This yields the following equation

$$(8) \quad pts_i = \alpha X_i + \pi_1 z_1 + \pi_2 z_2 + \pi_3 z_3 + v_i$$

where αX denotes all other exogenous variables of equation (7), z_i stands for three instrument variables, and v_i is the error term. Choosing the appropriate instrument is critical. In this instance, we took precipitation and solar radiation during the early growing season (from April to July) and solar radiation for the ripening period (August and September). The data were taken from California Department of Water Resources (2004). We computed the residuals $\hat{v}_i$ of the auxiliary regression, included them into equation (7) and re-estimated the equation. If the OLS estimates are consistent, then the coefficient on the first stage residuals should not be significantly different from zero. In our case, the parameter value of the residuals is 0.033. With a t-score of 1.32 it is statistically insignificant. Hence, the test suggests that the point-variable is indeed exogenous and OLS estimates are consistent.

The variable was included in its linear form because this specification yielded the best goodness to fit and the RESET values indicate that this is the most appropriate form. The OLS estimate of equation (7) is shown in Table 9.

Another potential issue may be the problem of multicollinearity. Table 10 reports the variance inflation factors (VIF)[10] for each variable of equation (7). Accordingly, multicollinearity is only caused by the two temperature terms. Clearly, growing season temperature and its squared value are closely correlated. However, given the significant t-scores for both variables, we decided not to alter the specification. In addition, a drop of one of the temperature variables would cause a substantial decrease in the goodness to fit by almost 9%.

Comparing the estimates for equation (5) and equation (7), we notice that the inflation controlling time variable falls from 8.1% to 6.5%. Hence, critical points capture some part of the wine price inflation, which is also expressed in a positive correlation of 0.310 between both variables.[11]

The estimated parameter for the time variable is to be interpreted as the average annual price increase of Pinot Noir wines between 1998 and 2003. However, given the stagnation or decrease in vineyard prices after 2000 (see Table 7) we suspected a

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[10] $VIF(\hat{\beta}_i)$ is calculated as $1/(1-R_i^2)$, where R_i^2 is the unadjusted coefficient of determination of an auxiliary regression in which X_i is a function of all the other explanatory variables in the equation. Thus there is an R_i^2 and a VIF for each X_i (e.g., Greene, 2003; Studenmund, 2001).

[11] The auxiliary equation in which critical points are a function of all other explanatory variables shows a significant marginal effect of 0.4 of the time variable (t-value = 2.92), i.e., critical scores increase by 0.4 points per year, holding other factors constant.

structural break and applied a dummy variable approach (Greene, 2003) to account for structural instabilities. We estimated equation (7) where the term ($\alpha_1 t_i$) was replaced with ($\lambda_i D_i + \alpha_1 t_i + \lambda_3 D_i t_i$). D$_i$ is a time-dependent dummy variable that takes on the value one for 1998, 1999, or 2000 and zero otherwise.[12] This approach allows one to control for a differential intercept (λ_2) as well as for a differential slope coefficient (λ_3). However, none of the λ coefficients was significant, suggesting structural stability of the time variable over the entire observation period.

Although the point-variable is statistically significant, with 3.2% (i.e., the difference between 78.3% and 81.5%) the contribution to the overall goodness to fit of the equation is comparatively small. Thus, scores assigned by wine experts do not add substantial explanatory value to publicly available fundamentals, such as climate, regional and personal variables.[13]

The estimate for equation (7) confirms the optimal growing season temperature of approximately 133^{o}C already derived from equation (5). Figure 2 shows the actual temperature conditions in selected Pinot Noir regions compared to the optimal value. It also shows that the temperatures at U.S. weather stations are above the optimum. Therefore, Pinot Noir vineyards must aim at vineyard-specific meso-climates below these values. In other words, since temperatures in American Pinot Noir regions are already above their optimal level, a cool year is a good wine year. Global warming will lead to decreasing prices.

The opposite is true in Western Europe. Temperatures in Burgundy and the German Pfalz are still below the optimal level. Vineyard-specific meso-climates should be warmer than at the weather stations. Although we did not investigate this empirically, we suspect that warmer years produce better Pinot Noir vintages.[14] Global warming, up to a certain

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[12] Similarly, we also controlled for possible structural breaks in 1999 and 2001.

[13] Note that a specification that considers the critical points as a squared term does not improve the equation and leads to almost identical results.

[14] For instance, many critics consider 1999 the best vintage for red Burgundies in more than a decade (e.g., Parker, 2004).

degree, should, therefore, lead to higher wine prices. However, given European precipitation patterns and the dependency of vines on rainfall (e.g., Ashenfelter et al., 1995), Figure 2 gives only an incomplete picture.

4 Summary

This paper analyzes price determinants of American Pinot Noir wines. The data is a sample of 451 wines reported and reviewed in *Wine Spectator.* The wines represent vintages from 1994 through 2001, and were grown in 19 different regions in both California and Oregon. Price data, given as suggested retail prices, were related to quantity produced, regional climate data, regional and personal dummy variables, and ratings given to each wine by *Wine Spectator*. It has been shown that American Pinot Noir prices are determined largely by fundamentals such as climate variables. In addition, dummy variables for regions and producers significantly enhance the results. Wine ratings by critics add only little explanatory value to the equation.

The main findings regarding climatic variables can be recapped as follows.

(1) In contrast to findings for European wines, the relationship between Pinot Noir prices and growing season temperatures is not linear but quadratic. The optimum temperature approximates a *good* vintage in Burgundy. Given the quadratic relationship, global warming is not necessarily good news for American Pinot Noir vintners. In fact, temperature increases above the optimum can entail a drop in prices. However, this is a static view and does not take into account substitution processes. For example, higher temperatures might force Pinot Noir viticulture to move into cooler areas, such as coastal regions. In fact, it can be argued that some substitution has already occurred, fostering investments in still Pinot Noir in areas that were considered suitable only for sparkling wine production thirty years ago.

(2) Regional weather data appear not to reflect the climate of specific vineyards. Given the distances between weather station and vineyard of often more than 20 miles, regional

climate data turned out to be very noisy. Disregarding regional climate data and referring to Carneros weather only (i.e., allowing for year-on-year variations only) the results improves substantially.

(3) Precipitation variables, both for winter and harvest, are insignificant. Compared to European vineyards, California and Oregon are very privileged. Winter rainfall is much higher than in Burgundy, but growing season rain is very rare. Even in Oregon, there has been no rain-compromised harvest since 1997.

(4) Overall, with an R^2 of about 0.52 American Pinot Noir prices are significantly less determined by climate variables than are European wines. For instance, both Ashenfelter et al. (1995) and Jones and Storchmann (2001) report a goodness to fit of substantially higher than 0.8 for Bordeaux wines.

(5) Therefore, regional dummy variables and dummy variables that reflect some combination of winemaking skills, brand reputation and explicit pricing policies take a big share in explaining price variations. By including these variables the goodness to fit increases by more than 25%.

(6) Wine ratings by critics, on the other hand, do not add much explanatory value to the equation drawing on fundamentals. The inclusion of critical scores, although highly significant, adds less than 4% to the overall goodness to fit.

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Table 1
Acreage, Crop Yield, and Prices of Selected Grape Varieties in California

	Grape Bearing Acreage in 1000 hectares			Crushed 1000 tons	Yield ton/ha	Price $/ton	Revenue $/hectare	Value of total Production[1] mill $
	1995	2000	2004	2004	2004	2004	2004	2004
	Red Wine Grapes							
Cabernet Sauvignon	13.40	19.32	28.95	360.2	12.44	977.7	12,163	352.1
Zinfandel	13.57	18.86	19.73	321.9	16.32	473.5	7,728	152.5
Merlot	4.49	16.83	20.67	392.2	18.97	799.3	15,163	313.4
Pinot Noir	3.40	4.71	9.16	70.1	7.65	1620.2	12,395	113.5
Rubired	2.95	4.34	4.49	158.4	35.28	209.9	7,405	33.2
	White Wine Grapes							
Chardonnay	23.46	35.71	37.81	524.7	13.88	693.8	9,630	364.1
French Colombard	17.92	16.82	11.60	251.0	21.64	201.4	4,358	50.6
Chenin Blanc	9.28	7.65	4.55	84.6	18.59	234.2	4,354	19.8
Sauvignon Blanc	4.32	4.32	5.27	78.8	14.95	691.7	10,341	54.5
Source: California Agricultural Statistics Service CASS (2003a, 2003b). [1] Value of crushed grapes.								

Table 2
Descriptive Statistics of Variables

Variable	Acronym	Minimum	Maximum	Mean	Standard Deviation
Retail Price	p	6	81	30.59	13.26
Time of Review (1998=1)	t	1	6	2	1.43
Age of Wine, years	age	2	4	2.25	0.45
Production, cases	prod	25	100,000	3334.1	9276.6
Max. Temperature Sum Growing Season (Mar-Sept), ^{0}C	temp	122.6	171.2	149.8	10.76
Precipitation Winter (Sum Dec-March), mm	prec_wi	58.67	1366.98	470.59	267.45
Precipitation Fall (Sum Aug and Sept), mm	prec_fa	0	107.00	14.24	20.95
Critics' Rating, points	pts	70	94	86.16	3.01
Source: The Wine Spectator (1998-2003), California Department of Water Resources (2004), Oregon Climate Service (2004).					

Table 3
Average Growing Season Temperature in Pinot Noir Regions

30 year average maximum temperature in ^{0}C

	April	May	June	July	Aug	Sept	SUM	Avg. growing season	Average July - Sept
Dijon/France	16	20	23	26	25	22	132	22.0	24.3
Karlsruhe/Germany	15	19	23	25	25	21	128	21.3	23.7
Geneva/Switzerland	13	18	22	24	24	21	122	20.3	23.0
Salem/Oregon	16	19	23	28	28	25	139	23.2	27.0
Napa/California	22	24	27	28	28	28	157	26.2	28.0
Paso Robles/Cal.	23	27	32	34	34	32	182	30.3	33.3
Source: http://www.weather.com.									

Table 4
Regional Weather Stations

Weather Stations	No.	Covered Wine Area
Arroyo Seco	#114	Santa Lucia Highlands
Carneros	#109	Carneros
Green Valley Road	#111	Santa Cruz Mountains
Oakville	#77	Napa Valley
Hopland	#85	Mendocino, Anderson Valley
Mc Minnville	n.a.	Willamette Valley (Oregon)
Novato	#63	Marin County
Roseburg	n.a.	Umpqua Valley (Oregon)
Salinas South	#89	Monterey
San Luis Obispo	#52	Arroyo Grande Valley, Edna Valley, Paso Robles
Santa Barbara	#107	Santa Barbara
Santa Rosa	#83	Sonoma Coast
Santa Ynez	#64	Santa Rita Hills
Windsor	#103	Sonoma Mountains, Russian River Valley
Source: California Department of Water Resources (2004), Oregon Climate Service (2004).		

Table 5
Descriptive Price Statistics by Regions

Region	Number of Observations	Minimum	Maximum	Mean	Standard Deviation
Anderson Valley	19	14	50	28.11	10.81
Arroyo Grande Valley	12	18	50	34.00	9.87
Carneros	67	14	80	31.88	16.26
Edna Valley	9	16	33	25.00	6.40
Marin County	1	40	40	40.00	--
Mendocino	5	13	35	20.00	8.63
Monterey	16	7	60	23.56	13.95
Napa Valley	10	18	45	27.60	8.57
Paso Robles	1	30	30	30.00	--
Russian River Valley	81	12	80	33.42	14.29
Santa Barbara	71	13	55	29.45	9.30
Santa Cruz Mountains	9	16	50	30.78	9.61
Santa Lucia Highlands	21	18	56	35.57	11.49
Santa Rita Hills	17	27	55	37.29	7.79
Sonoma Coast	15	18	65	36.67	12.41
Sonoma Mountains	5	17	40	27.60	9.29
Sonoma Valley	14	14	81	28.29	16.92
Umpqua Valley	3	15	34	22.00	10.44
Willamette Valley	36	9	63	36.75	13.10
Regional Blends	39	7	45	19.29	9.32

Source: see text.

Table 6
OLS Estimates of Basic Equations

Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	equation (2)	equation (6)	equation (4a) with constant	equation (4b) with constant	equation (4a) no constant	equation (4b) no constant	equation (4b) no constant Carneros Climate[b]
	n=451	n=451	n=412 [a]	n=412 [a]	n=412 [a]	n=412 [a]	n=451
Constant	2.617** (24.46)	1.975** [18.67]	3.482** [13.78]	-2.399 [-1.16]			
Time	0.099** (7.45)	0.043** [3.50]	0.099** [9.80]	0.101** [10.05]	0.161** [13.48]	0.100** [10.01]	0.090** [6.00]
Age	0.193** (4.59)		0.117** [3.17]	0.114** [3.11]	0.211** [5.18]	0.114** [3.11]	0.159** [3.49]
log(Production)			-0.129** [-10.51]	-0.132** [-10.65]	-0.073** [-5.10]	-0.131** [-10.66]	-0.150** [-13.22]
Designated Vineyard			0.167** [5.21]	0.163** [5.09]	0.236** [5.98]	0.164** [5.14]	0.171** [5.57]
Temperature Growing Season			0.0008 [0.56]	0.081** [2.89]	0.018** [20.63]	0.049** [21.25]	0.056** [11.16]
(Temp. Growing Season)^2				-0.0003** [-2.87]		-0.0002** [-14.09]	-0.0002** [-7.09]
Precipitation Winter			0.000 [0.25]	0.000 [0.15]	0.0001 [1.76]	0.000 [0.17]	-0.000 [-0.20]
Precipitation Harvest			-0.0006 [-0.79]	-0.0007 [-1.01]	-0.0019* [-2.20]	-0.0006 [-0.91]	0.005 [1.83]
Points		0.076** [11.48]					
R^2	0.136	0.351	0.444	0.453	0.192	0.451	0.524
adj. R^2	0.132	0.348	0.434	0.442	0.180	0.442	0.517
F-statistic	35.11	121.23	46.01	41.70	13.79	41.55	55.65
Standard Error	0.402	0.348	0.299	0.297	0.360	0.297	0.299
White's Test	[$\chi^2(4)$]=1.7	[$\chi^2(4)$]=13.8	[$\chi^2(22)$]=33.6	[$\chi^2(22)$]=35.4	[$\chi^2(22)$]=60.4	[$\chi^2(22)$]=35.0	[$\chi^2(22)$]=17.6
RESET Test[c]	2.315*	7.607	0.715**	0.562**	93.776	0.984**	2.256**

t-statistics in parenthesis, heteroscedasticity-constistent t-statistics in brackets. ** 2% significance level, * 5% significance level. [a] lower sample size because no climate date for 39 regional blends available. [b] climate data for Carneros only, no regional data. [c] the RESET test statistic is distributed as an F-statistic.

Table 7
Average Prices for Vineyard Land in California

in 1000 $ per hectare, 1992 to 2002

County	1992	1995	2000	2002	annual increase 1992/2002
Napa	125	110	312.5	287.5	8.7%
Sonoma	75	87.5	237.5	193.8	10.0%
Mendocino	42.5	47.5	125	97.5	8.7%
Monterey	20	24.5	46.3	55	10.6%
San Luis Obispo & Santa Barbara	33.8	38.8	57.5	69.5	7.5%

Source: American Society of Farm Managers and Rural Appraisers, 2003.

Table 8
Average Precipitation in Pinot Noir Regions
30 year average in millimeter

	December	January	February	March	Precipitation Winter (Dec-Mar)	Precipitation Fall (Aug and Sept)
Dijon/France	58.4	40.3	40.6	48.3	187.6	116.8
Karlsruhe/Germany	66.0	55.9	53.3	53.3	228.5	119.3
Geneva/Switzerland	81.3	73.7	73.7	73.7	302.4	157.4
Salem/Oregon	164.1	148.3	129.3	105.9	547.6	53.6
Napa/California	98.6	135.9	127.8	103.9	466.2	13.2
Paso Robles/Cal.	43.9	71.9	72.9	67.6	256.3	10.6
Source: http://www.weather.com						

Table 9
OLS estimates of extended equations

	equation (5)	equation (7)		equation (5)	equation (7)
	n=451 df=330	n=451 df=329			
Time	0.081** [4.80]	0.065** [3.92]	Russian River Valley	0.210** [2.82]	0.224** [3.13]
Age	0.126** [2.86]	0.080 [1.87]	Santa Barbara	0.123 [1.69]	0.135 [2.07]
log(Production)	-0.171** [-11.55]	-0.144** [-9.95]	Santa Cruz Mountains	-0.000 [-0.00]	0.019 [0.18]
Designated Vineyard	0.090** [2.40]	0.080** [2.35]	Santa Lucia Highlands	0.018 [0.20]	0.059 [0.76]
Temperature Growing Season	0.057** [10.13]	0.047** [8.48]	Santa Rita Hills	0.081 [0.89]	0.091 [1.19]
(Temp. Growing Season)^2	-0.0002** [-6.85]	-0.0002** [-5.94]	Sonoma Coast	0.077 [0.68]	0.077 [0.85]
Precipitation Winter	0.0001 [0.48]	0.0004 [1.71]	Sonoma Mountains	-0.014 [-0.11]	-0.010 [-0.08]
Precipitation Harvest	0.005* [2.22]	0.002 [0.92]	Sonoma Valley	0.016 [-0.17]	0.076 [0.81]
Anderson Valley	0.072 [0.96]	0.045 [0.71]	Umpqua Valley/Oregon	-0.338* [-1.90]	-0.310 [-1.55]
Arroyo Grande	0.183 [1.84]	0.179* [2.06]	Willamette Valley/Oregon	0.120 [0.95]	-0.011 [-0.11]
Carneros	0.252** [3.14]	0.248** [3.58]	Etude	0.580** [7.85]	0.532** [6.89]
Edna Valley	-0.066 [-0.80]	-0.066 [-0.84]	Saintsbury	0.549** [4.02]	0.396** [2.92]
Marin County	-0.180 [-1.35]	0.004 [0.03]	Williams Selyem	0.472** [4.82]	0.337** [3.82]
Mendocino	-0.314** [-3.62]	-0.128 [-1.55]	Signorello	0.428** [5.94]	0.376** [6.18]
Monterey	-0.099 [-0.85]	0.029 [0.22]	Cambria	0.371** [4.40]	0.326** [4.26]
Napa Valley	0.213 [1.62]	0.268** [2.63]	Brophy	-0.529** [-5.36]	-0.523** [-4.26]
Paso Robles	-0.000 [-0.00]	0.147* [2.20]	Wine Spectator Points		0.042** [6.92]
R2	0.783	0.815	SSE	0.235	0.217
adj. R2	0.704	0.747	White's Test	$[\chi^2(128)]=136.3$	$[\chi^2(130)]=144.4$
F-statistic	9.841	11.091	RESET Test [a]	1.174**	0.679**

heteroscedasticity-constistent t-statistics in brackets. ** 2% significance level, * 5% significance level.

[a] the RESET test statistic is distributed as an F-statistic.

Table 10
Variance Inflation Factors for Equation (7)

Variable	$VIF(\hat{\beta}_i)$ [a]
Time	4.89
Age	3.57
Production	1.69
Designated Vineyard	2.34
Temperature Growing Season	11.90
(Temp. Growing Season)^2	35.71
Precipitation Winter	4.10
Precipitation Harvest	4.52
Points	2.62

[a] multicollinearity is assumed to be present when $VIF(\hat{\beta}_i) > 5$ (Studenmund, 2001).

Figure 1
Sum of Average Maximum Temperatures during the Growing Season at Selected Weather Stations

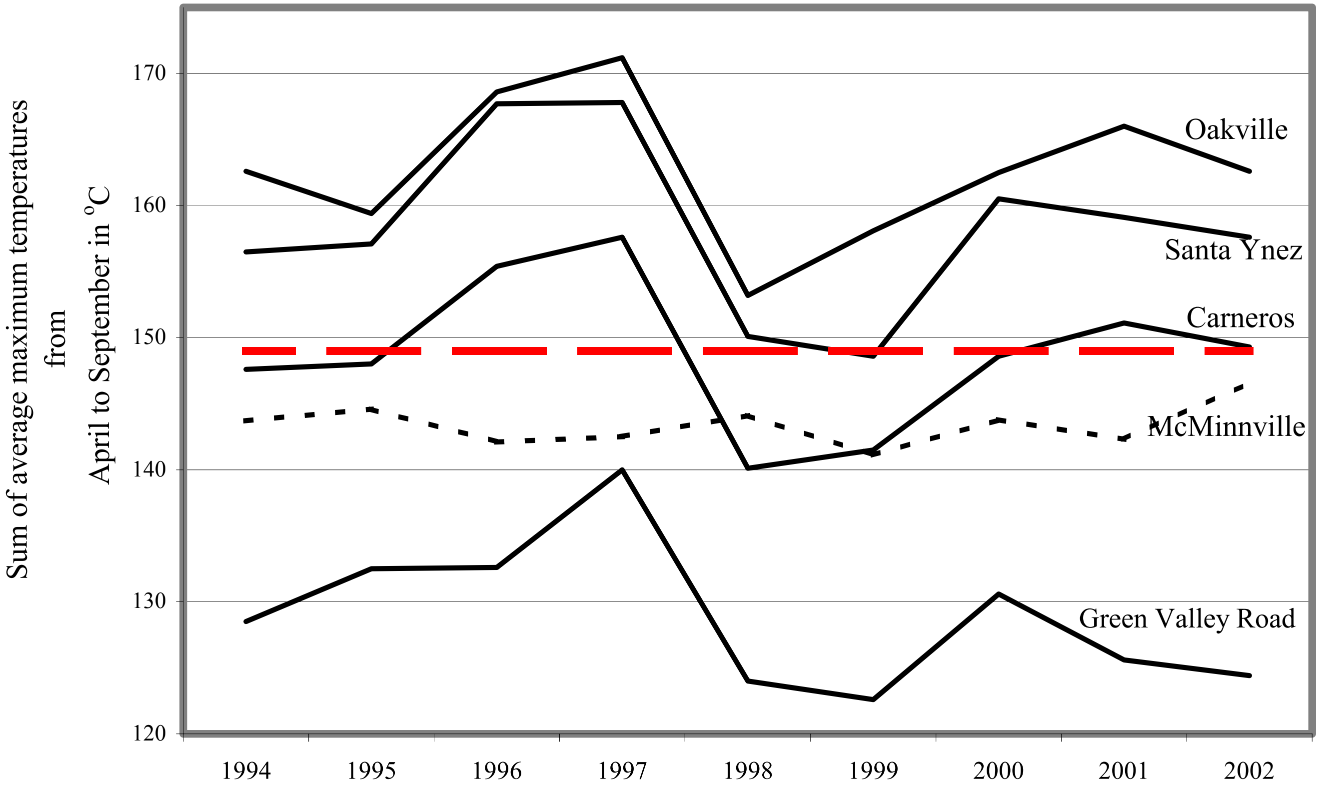

Figure 2
Optimal and Actual Temperatures in Selected Pinot Noir Regions
from 1989 to 2003