Splendide Mendax:[†]
False Label Claims about High and Rising Alcohol Content of Wine

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[†] *Splendide mendax*: Nobly untruthful; untrue for a good object.

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Splendide Mendax:
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ABSTRACT. Many economists and others are interested in the phenomenon of rising alcohol content of wine and its potential causes. Has the alcohol content of wine risen—and if so, by how much, where, and when? What roles have been played by climate change and other environmental factors compared with evolving consumer preferences and expert ratings? In this paper we explore these questions using international evidence, combining time-series data on the alcohol content of wine from a large number of countries that experienced different patterns of climate change and influences of policy and demand shifts. We also examine the relationship between the actual alcohol content of wine and the alcohol content stated on the label. The systematic patterns here suggest that rising alcohol content of wine may be a nuisance by-product of producer responses to perceived market preferences for wines having riper, more-intense flavours, possibly in conjunction with evolving climate.

Key Words: Winegrapes, alcohol percentage, climate change, labeling errors

1. Introduction

Initial motivation for the work in this paper came from an observation that the sugar content of California wine grapes at harvest had increased by more than 11 percent from 21.4 degrees Brix in 1980 (average across all wines and all districts) to 23.8 degrees Brix in 2007.[1] Since sugar converts essentially directly into alcohol, an 11 percent increase in the average sugar content of wine grapes implies a corresponding 11 percent increase in the average alcohol content of wine. We set out to explore whether this phenomenon of rising sugar content of grapes was indeed reflected in rising alcohol content of wine, and to see if we could distinguish between causes related to climate change versus other causes related to evolving market preferences, as indicated by expert ratings for wines, and government policies that discourage the production of wine with higher alcohol content.[2]

Accurate detailed data on the alcohol content of California wines are not generally available. While every wine bottle reports a figure for alcohol content on the label, the tolerances are wide and the information content is therefore limited. Specifically, U.S. law allows a range of plus or minus 1.5 percent alcohol for wine with 14 percent alcohol by volume or less, and plus or minus 1.0 percent for wine with more than 14 percent alcohol by volume. Moreover, wineries may have incentives to deliberately distort the information because the tax rate is higher for higher alcohol wine (the Federal Wine Excise Tax is $1.07 per gallon for wine 14% alcohol or less, $1.57 per gallon for wine 14.1% to 21% alcohol, and $3.40 per gallon for

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[1] Degrees Brix (°Bx) is a measurement of the relative density of dissolved sucrose in unfermented grape juice, in grams per 100 milliliters. A 25 °Bx solution has 25 grams of sucrose sugar per 100 milliliters of liquid. The percentage of alcohol by volume of the finished wine is estimated to be 0.55 times the °Bx of the grape juice.

[2] A literature on the economic effects of weather and climate on wine economics has developed over the past 20 years, with contributions such as Ashenfelter, Ashmore and Lalonde (1995), Ashenfelter and Byron (1995), Nemani et al. (2001), Tate (2001), Jones (2005, 2006, 2007), Jones et al. (2005), Webb et al. (2005), White et al. (2006), Jones and Goodrich (2007), Ashenfelter (2008), and Ashenfelter and Storchmann (2010). Issues addressed include various aspects of wine quality, yield, and the optimal location of production.

sparkling wine) or because they perceive a market preference for a particular range of alcohol content for a given style of wine. Consequently, label claims concerning alcohol content may be misleading. However, the Liquor Control Board of Ontario (LCBO), which has a monopoly on the importation of wine for sale in the province of Ontario, Canada, tests every wine it imports and records a number of characteristics including the alcohol content. Alston et al. (2011) reported results from the analysis of the sugar content of California winegrapes and the alcohol content of California wine imported by the LCBO, which indicated (a) that climate change does not appear to account for much of the recent increase in sugar content of grapes or in the alcohol content of wine in California, and (b) the label claims about the alcohol content of wine exhibit systematic errors.

In the present paper we explore the same questions using international evidence, combining 16 years of time-series data from the LCBO on the alcohol content of wine from a large number of countries that experienced different patterns of climate change and influences of policy and demand shifts. In addition, we conduct an analysis of the discrepancies between the actual alcohol content of wine and the content claimed on the label. This analysis is motivated in part because the issue of high and rising alcohol content of wine is intrinsically interesting and has attracted some interest in the media; including some attention to inaccurate label claims.[3]

2. Evidence on the Rising Alcohol Content of Wine and the Role of Climate

The first phase of work in this paper examines the changes in alcohol content of wine from the world's main wine-producing regions over a period of nearly two decades. As well as

[3] In an article in the *San Francisco Chronicle* on April 24, 2011, Jon Bonné discussed concerns about the alcohol content of wine, and announced that the *Chronicle* would henceforth publish the listed alcohol content for every wine recommended in the Food & Wine section. The article reported the results of tests of 15 premium wines finding that the actual alcohol percentage exceeded the stated alcohol percentage in a majority of instances by more than 0.5 percentage points and in two instances by more than 1.0 percentage points.

describing the patterns in the data we attempt to account for the role of changes in climate, as measured by an index of heat (average daily temperature) in the growing season.

Data for the Analysis

The LCBO provided us with data for 18 years (1992–2009) comprising 129,123 samples of wines, including 80,421 red wines and 46,985 white wines from all around the world. The amount of detail reported varies widely among the observations; some contain information on the brand and variety name, others only the variety; some report only country of origin, while others refer to smaller regions within countries, or other details of the appellation reported on the label. In the early stages of the analysis we decided to set aside the data for German wines because they entail substantial differences in winemaking styles and techniques—emphasizing white wines with significant residual sugar, mainly Riesling, for which many of the structural relationships could be expected to be different than their counterparts for dry table wines that predominate elsewhere. We also opted to exclude other wines that were clearly dessert wines, either because of other indications or because they reported very high alcohol content (more than 17 percent by volume); we also excluded wines having total residual sugar above 1 percent or volatile acidity above 10 percent or very low alcohol (less than 8 percent); and the observations for 2008 and 2009 were set these aside because they were incomplete and appeared to have some other problems. Of the remaining observations 91,432 were usable in that they were non-duplicates that included data on the actual alcohol percentage, the alcohol percentage stated on the label, the vintage year, and the country (and, in some cases, the region) of origin.

We acquired corresponding region-specific climate data from several sources. We obtained data recorded by various weather stations, and worked to identify those weather stations that would provide the best representation of the respective growing regions. Where it was available, we used weather station data from NOAA's National Climatic Data Center (1992–2007). Climate data in the form we desired were not available for New Zealand or South Africa from NOAA. Instead we were able to obtain information for New Zealand from the Marlborough Wine Research Centre (1992–2007), and for South Africa from Irene van Gent AgroMet-ICSW, per. comm., (1992–2007). To create a useful heat index, we averaged the daily high and low temperatures over the relevant growing season (April–October in the northern hemisphere, October–April in the southern hemisphere). We refer to this variable as the average daily temperature over the growing season, or the heat index.[4]

Base Values and Growth in Alcohol Percentages and Growing Season Temperatures

Table 1 includes summary statistics on the numbers of observations for each type of wine (red, white, or both red and white pooled) for each country and the average actual alcohol percentage recorded for that country in 1992, and the average value of the heat index for the sample period, 1992–2007. The spatial patterns in the alcohol content of wine in 1992 are consistent with expectations generally. Specifically, "Old World" wines tend to have lower alcohol percentages than "New World" wines; wines from cooler places (e.g., Canada and New Zealand) tend to have lower alcohol percentages than wines from hotter places (e.g., the United States and Australia); and red wines tend to have higher alcohol percentages than white.

[Table 1: *Alcohol Content and Heat Index: Base Values and Percentage Changes, by Country*]

Table 1 also includes two measures of the growth rate of the alcohol percentage and the heat index: the average of annual percentage changes and the trend growth rate from a semi-logarithmic regression (details of these regressions are included in Appendix Tables A-1 and A-2). All of the trend coefficients for alcohol are highly statistically significant, indicating growth

[4] We thank Professor Andrew Walker from the Department of Viticulture and Enlogy at UC Davis for advising us about the appropriate choice of a heat index for our purpose.

in the alcohol percentage in every country, but at different rates (with the trend rate sometimes quite different from the average annual rate).[5] The growth rates range between about 0.1 and 1.0 percent per year implying total growth of 1.5 to 16.0 percent over 16 years (i.e., an increase in the average alcohol content of between 0.2 and 2.0 percent alcohol on a base of 12–13 percent).[6]

Table 2 includes the same information as in Table 1, but now for sub-national regions, which were defined based on an inspection of the data, and in consideration of the availability of data for some regions relative to others (the counterpart growth-rate regressions are included in Appendix Tables A-3 and A-4). The disaggregated regions have much more disparate patterns in the growth rates, partly reflecting the relatively small sample sizes in some cases. While the model fit was poor for these specifications, the estimated growth rate was positive and highly significant for each regional specification, with the exception of "Canada Other," representing wine growing regions of Canada outside British Columbia and Ontario, or observations without a designated growing region. In the heat index regressions, the specific regions within France (Bordeaux, Burgundy, Languedoc, Rhone, and France Other) and Italy (Piedmont, Tuscany, Veneto, and Italy Other) all had statistically significant growth rates.

[Table 2: *Alcohol Content and Heat Index: Base Values and Percentage Changes, by Region*]

Regressions of Alcohol Percentage against the Heat Index

We pooled the data across countries, years, and types of wine and ran a series of regressions to explore the effects of climate change, as represented by the heat index, as a potential contributor to the rising alcohol content of wine. The alcohol percentage by volume is

[5] Each approach has advantages and disadvantages. The average of annual proportional changes is dominated by end-points to the series, which is a disadvantage if the endpoints might contain large idiosyncratic elements or measurement errors, but can be an advantage if measurement errors are negligible. A trend line will most likely not pass through the end-points and will not be dominated by measurement error in the end-points but may be influenced by other outliers, functional form and other specification errors, and other general problems with the linear regression model. We can hope that the two measures might bracket the truth.

[6] We report robust standard errors in all regressions.

the dependent variable in all of the regression models reported in Table 3.[7] In column (1) we show the results of regressing the alcohol percentage against a linear time trend. The coefficient is positive and statistically significantly different from zero at the one percent level of significance. It indicates that, on average, across the data, the predicted alcohol content of wine increased by 0.07 percentage points per year, or 1.12 percentage points over the 18 years relative to an initial mean of 12.7 percent alcohol by volume; an increase by one-tenth in the average alcohol content of wine.

[Table 3: *Regressions of Alcohol Percentage Against Trend and Temperature*]

The model in column (2) also includes our climate variable, the average growing season temperature in degrees Fahrenheit. Both coefficients are positive and statistically significant at the one percent level. The coefficient on the trend variable is a little smaller than in column (1), indicating an underlying growth rate in alcohol content of 0.06 percentage points per year, after accounting for the effects of temperature changes. The coefficient on the heat index is approximately 0.05, suggesting that a one-degree Fahrenheit increase in the average growing season temperature everywhere in the world would cause the average alcohol content of wine to increase by 0.05 percentage points; it would take a whopping 20 degree Fahrenheit increase in the average temperature in the growing season to account for a 1 percentage point increase in the average alcohol content of wine. In the other models in Table 3, with additional explanatory variables included, the measured effect of the heat index is, if anything, even smaller, while the general results for the effects attributable to the trend are roughly constant.

The other models in Table 3 progressively introduce dummy variables to allow different intercepts (fixed effects) for white wine versus a default of red wine in column (3); for Old

[7] Appendix Table A-5 includes the results from regressions with the dependent variable in natural logarithms, instead. The results are essentially the same.

World wines versus a default of New World wines in column (4); and by country of origin versus a default of France (such that the combined default category is red wine from France) in column (5). In column (6) the model in column (5) is augmented with interactions between country and trend such that we have individual slope and intercept dummies allowing for different growth rates of alcohol content among countries, with common coefficients to adjust for the difference between red and white wine, and the effects of region-specific temperatures.

In all of these models every coefficient is statistically significantly different from zero at the 1 percent level of significance, with one exception (the coefficient on the time-trend dummy for Argentina), and the coefficients are plausible. The white wine effect in column (3) is approximately – 0.5, indicating that we can expect white wines generally to have about 0.5 percentage points less alcohol than red wines. In column (4) the estimates indicate that we can expect Old World (European) wines to have about 0.63 percentage points less alcohol than wine produced in the New World (the Americas, Australia, New Zealand, and South Africa). The latter effect is not measured in the other models; columns (5) and (6) report country-specific fixed effects instead. In column (5) the effects of the country dummies indicate that, compared with France, three countries produce somewhat lower-alcohol wine (Canada, New Zealand, and Portugal) while the rest produce higher-alcohol wine, with the effects being most pronounced for Australia (0.55 percentage points higher on average) and the United States (0.85 percentage points higher on average).

The results of the model in column (6) are slightly harder to interpret because we now have, in effect, color-of wine- and country-specific time-trends as well as intercepts. The coefficients on the trend interaction terms measure the additional trends, relative to the default, which is red wine from France. The coefficient of – 0.0348 on "white×trend" measures the difference in the trend growth rate. It indicates that, compared with French red wine, for which the alcohol content grew by 0.0667 percentage points per year, the alcohol content of French white wine was growing more slowly, at a rate of 0.0667 – 0.0348 = 0.0312 percentage points per year; less than half the rate for red. The "country×trend" interaction terms indicate that, compared with French wine for which it grew by 0.0667 percentage points per year, the alcohol content grew somewhat faster in every other country except Italy. For instance, the coefficient of 0.0220 on "Australia×trend" indicates that the alcohol content of Australian red wine grew by 0.0667 + 0.0220 = 0.0887 percentage points per year, implying an accumulated increase over 18 years of 1.4 percentage points for red wine. Combining this with the coefficient of – 0.0348 on "white×trend" indicates that the alcohol content of Australian white wine grew by 0.0667 + 0.0220 – 0.0348 = 0.0539 percentage points per year, implying an accumulated increase over 18 years of 0.9 percentage points for white wine. These estimates are comparable to those implied by the proportional growth rates reported in Table 1 for Australian wine.

The main lesson from the results in Table 3, combined with the information in Tables 1 and 2 is that the heat index does not account for much of the growth in the average alcohol content of wine for two reasons. First, the heat index did not increase by very much in most places, perhaps especially in those places that exhibited the fastest growth in alcohol content of wine (Australia and the United States). Second, the estimated regression coefficient indicates that a very large change in the heat index would be required to bring about an appreciable increase in the alcohol content of wine. These findings parallel those from Alston et al. (2011) who found that a similar heat index for California did not contribute much to accounting for increases in either the sugar content of California winegrapes or the alcohol content of California wine. We are conscious of the possibility that our results might be fragile, conditional on our data and model specification choices, and our use of a measure of temperature that might not optimally capture the true impacts of changes in climate on wine production, but for now we must conclude that climate change has not been the main factor driving the steady, systematic, and pervasive rise in the alcohol content of wine.

3. Actual versus Reported Alcohol Percentages

The second main phase of work in this paper concerns the discrepancy between the actual alcohol content of wine and the alcohol percentage as stated on the label. These discrepancies are intriguing and intrinsically interesting, but they also may provide some insight into producers' perceptions of alcohol content as a characteristic of wine—whether it is valuable, a "good" characteristic, or alternatively a "bad," and under what circumstances—which in turn may help us understand the causes of the rise. We begin this part with an overview of the main patterns in the data, before turning to some attempts to interpret the patterns and discern causes.

Systematic Errors in the Reported Alcohol Percentage

Table 4 includes data on the actual and reported alcohol content of wine and the difference between the two, organized in various ways. First, consider the totals in the first row of the table, representing all 91,432 observations. These data show that the average actual alcohol content was 13.30 percent alcohol by volume, the average reported alcohol content was 13.16 percent alcohol by volume, and the average discrepancy between the two (reported minus actual, such that a positive value means the actual alcohol content was overstated on the label and a negative value means the actual alcohol content was understated on the label) was – 0.13 percent alcohol by volume. This refers to the entire population of our data. Reading across the same row, we can see the corresponding statistics separately for red and white wine and for wine from different regions of the world, the New World and the "Old World." The data show that the average error was a little higher for New World wines compared with Old World wines, but similar for red and white wine. In the other rows of this table, we report the corresponding statistics for each year of the sample. Setting aside the first few years, for which the sample were relatively small and the reporting errors were very small for Old World wines, it is not apparent that the size of the errors has trended up, though the actual and reported alcohol percentages do appear to have trended up.

[Table 4: *Alcohol Reporting Error by Year*]

Table 5 includes some comparable summary statistics on the reported and actual alcohol content of wine, and the reporting errors, by country of origin of the wine. The propensity for reporting errors does vary among countries of origin in ways that are not fully attributable to differences in the actual alcohol content of the wine, possibly reflecting differences in regulations or other institutions, which may be an interesting subject for future analysis. The countries with the largest understatements of the alcohol content include Chile, Argentina, Spain, and the United States.

[Table 5: *Alcohol Reporting Error by Country and Type of Wine*]

Table 6 is comparable to Table 5, except that the data are sorted into groupings according to whether the alcohol content of the wine was overstated or understated on the label. The first block of entries in Panel a of Table 6 replicates the information from Tables 4 and 5 for the sample as a whole, but with some additional detail, including a *t*-statistic for testing the hypothesis that the discrepancy between the reported and actual alcohol content is zero (this is the *t*-statistic for a paired comparison). Throughout this table these *t*-statistics are generally very large, indicating that the measured discrepancies are statistically significantly different from zero. The next block of entries (Panel b in Table 6) refers to observations in which the alcohol content was understated; thee include 52,178 observations, 57.1 percent of the total here. The average actual alcohol content was 13.6 percent and the average reported alcohol percentage was 13.1 percent, with an average discrepancy of – 0.42 percentage points. The size of the understatement was similar between red and white wines, though the average actual alcohol content was 13.7 percent for red versus 13.2 percent for white, within this group. The patterns are a little different if we further split the data in this group between the New World and Old World sources. Compared with the New World wines, for both red and white wine, the Old World wines had lower actual alcohol content (by about 0.6 to 0.7 percentage points on average) and understated the alcohol content to a smaller extent (by 0.38 or 0.39 percentage points compared with 0.45 percentage points on both red and white wines from the New World).

[Table 6: *Reported versus Actual Alcohol Content of Wine by Color of Wine and Region*]

Labels for a significant, albeit smaller, number of wines (29,461, 32.2 percent of the sample) erred in the opposite direction, overstating the true alcohol content as shown in Panel c of Table 6. The average actual alcohol content for this group was 12.9 percent by volume and the average reported alcohol percentage was 13.2 percent, with an average discrepancy of 0.32 percentage points. Within this group, the size of the overstatement was similar between red and white wines, though the average actual alcohol content was 13.1 percent for red versus 12.6 percent for white, and similar between the New World and Old World sources, though the Old World wines had lower actual alcohol content (by about 0.5 percentage points).

A little over one-tenth of the useful sample observations (9,793) fell into the final category shown in Panel d of Table 6, wines for which the reported alcohol percentage was within 0.01 percentage points of the actual alcohol percentage. In this category, Old World red wine had an average alcohol content of 13.0 percent by volume; Old World white, 12.5 percent; New World red, 13.6 percent; New World white, 13.1 percent.

Considering Panels b, c, and d, in Table 6 we observe systematic patterns in the errors: a tendency to overstate the alcohol content for wine that has relatively low actual alcohol, and a tendency to understate the alcohol content for wine that has relatively high alcohol content. Indeed, even though the average actual alcohol content varies substantially among the panels for a given category of wine (e.g., the average for New World red in Panel b is 14.1 percent and in panel c it is 13.4 percent) the average reported alcohol content is virtually constant across panels (within 0.1 percent alcohol). It is as though the reported alcohol percentages are biased towards values of 13.0 percent by volume for Old World red, 12.5 percent for Old World white, 13.6 percent for New World red, and 13.1 percent for New World white.

A Theory of Demand for Labeling Errors

It is relatively inexpensive to measure the alcohol content of wine reasonably precisely (though some of the devices used may entail larger measurement errors), and it is necessary to do so to be informed enough to comply with tax regulations, at least in the United States. It is also an important element of quality control in winemaking. Consequently, we speculate that commercial wineries for the most part have relatively precise knowledge of the alcohol content of the wines they produce and that the substantial average errors that we observe are not made unconsciously. This speculation is based in part on informal discussions with some winemakers who have admitted that they deliberately chose to understate the alcohol content on a wine label, within the range of error permitted by the law, because they believed that it would be advantageous for marketing the wine to do so. In one instance, we were told specifically that the stated alcohol content was much closer to what consumers would expect to find in a high quality wine of the type in question. Here we develop a simple theoretical model of such behavior that gives rise to an empirical specification that we can use to estimate the "desirable" ranges of alcohol content for different types of wines towards which the label claims are biased.

Suppose winemakers perceive a demand function in which the price they can expect to receive for a given wine, *i* in a given year, *t*, is a nonlinear function of its attributes including variety, *V*; region of origin, *R*; the alcohol content stated on the label, *S* (which may differ from the actual alcohol content); other attributes, *X*, that winemakers might be able to control and which may vary from vintage to vintage (including whatever else may be printed on the label in addition to variables already listed); and other variables, *Z*, as follows:[8]

(1) $P_{it} = f(V_i, R_i, S_{it}, X_{it,} Z_t)$.

Winemakers can influence the alcohol content and other characteristics of the wine by choosing quantities of inputs and technology, at a cost, but cannot cheaply vary the quantity of alcohol independently from other characteristics. For instance, to achieve riper, more intense fruit flavors may require longer hang times that also imply more concentrated sugar and higher alcohol wine. Consumers may happily pay a premium for the resulting flavors yet prefer not to have (or, at least know, about) the concomitant increase in alcohol content. In such a setting, it may be profitable for the winery to give the consumer both the desired wine characteristics (including higher actual alcohol content) and the desired label characteristic, by understating the true alcohol content. This parable is consistent with explanations we have been given by some winemakers. An implication is that there exists an optimal (i.e., winery-profit-maximizing) or

[8] Many studies have estimated hedonic price functions to quantify the effects of various attributes of wine, as displayed on the label, on consumers' willingness to pay for the wine. Gustafson (2011) reviewed this literature. Costanigro, McCluskey, and Mittelhammer (2007, p. 455) noted that " . . . when regressing objective and sensory characteristics on wine price, the objective cues (such as expert rating score and vintage) are significant, whereas sensory variables (such as tannin content and other measureable chemicals) are not." Later in this paper we discuss an implication of our results that might account for this finding, even if the stated alcohol content of wine is something consumers do care about and that could significantly influence their wine market choices.

desired value for the stated alcohol content for any wine that is a function of all the other variables in equation (1). Assuming a simple linear form for this relationship:

(2) $S_{it}^{*} = \alpha_0 + \alpha_v V_i + \alpha_r R_i + \alpha_z Z_t.$

If there were no other cost associated with false label claims, the winery would simply apply the desired value, S^{*} regardless of the actual content. However, suppose the winery perceives a cost associated with the size of the discrepancy between the stated alcohol content, S_{it}, and the actual alcohol content, A_{it}, that it has to trade off against the cost of having a stated alcohol percentage that is different from the desired value, S^{*}. Specifically, assume the winery seeks to choose S_{it} to minimize a total cost which is quadratic function of both (a) the size of the discrepancy between the stated and actual alcohol percentage and (b) the difference between the stated alcohol percentage, S and the desired value, S^{*}:

(3) $\min_{S_{it}}[L_{it} = \beta(S_{it} - A_{it})^2 + (1-\beta)(S_{it} - S_{it}^{*})^2]\,.$

The solution to this optimization problem is:

(4) $S_{it} = \beta A_{it} + (1-\beta)S_{it}^{*}$

Using (2) to replace the unobserved "desired" value in (4), and subtracting the actual alcohol content from both sides yields the following model for the observed discrepancy between reported and actual alcohol content of wine:[9]

(5) $D_{it} = S_{it} - A_{it} = (\beta - 1)A_{it} + \gamma_0 + \gamma_v V_i + r_r R_i + \gamma_z Z_t.$

Regression Results

We implemented the model in equation (5) using our LCBO data. Table 7 includes the results from the estimation of five variants of this model. In the model reported in column (1), which includes a time trend and the actual alcohol percentage, the estimated coefficients imply a

[9] Note, the parameters in (5) may be interpreted using (2), as $\gamma_k = (1-\beta)\alpha_k$.

value of β = 0.78. If the actual alcohol content was 14 percent and the desired alcohol content was 13 percent, this value of β = 0.78 implies an optimal reported alcohol percentage of 13.8 percent. The coefficient on the time trend is positive and statistically significant, indicating that the desired alcohol content of wine has trended up over time, by 0.015 percentage points per year implying an accumulated increase of 0.24 percentage points over 18 years. The estimated values for β and the base time trend effect are relatively constant across the alternative models reported in columns (2) through (6) that include additional variables to represent growing season temperature and differences among regions of the world.

[Table 7: *Regressions of Reported minus Actual Alcohol Content by Country, 1992–2007*]

In column (2) of Table 7, we incorporated our heat index, which contributed significantly to the regression. In column (3) we added dummy variables for white wine and Old World so the default category is New World red wine. The estimated coefficients indicate that, ceteris paribus, desired alcohol percentages are lower by about 0.13 percentage points for white wine compared with red, and by about 0.10 percentage points for Old World wine compared with New World wine. These are plausible results.

Columns (4) and (5) include dummy variables to capture fixed effects for individual countries rather than the Old World dummy. In column (4), the coefficients on these dummy variables can be interpreted as indicating the difference between the desired alcohol percentage for red or white wine from that country compared with French wine. For most of the New World countries, the desired alcohol percentage is between 0.1 and 0.2 percentage points higher than the desired alcohol percentage for French wine.

In column (5) we have introduced time trends interacted with the white wine dummy and with country dummies, to measure country-specific trends in the desired alcohol content of wine.

The coefficient on the interaction of the trend with the dummy for white wine is negative but small, indicating that the trend in desired alcohol content of wine has been slower for white than red wine but nonetheless positive. The country-specific trends indicate that the positive trend in the desired alcohol content of wine has been faster for wine from every other country relative to France—indeed, more than twice as fast for most of the New World countries, but fastest of all for Portugal.

"Optimal" Alcohol Content

We can infer values for the desired alcohol content for a given wine as a function of its characteristics by using the estimated parameters from (5) in equation (2). Alternatively, for any particular observation or set of observations, we can simply use the estimated value for β in conjunction with the stated and actual alcohol content:

$$(6) \qquad S_{it}^{*} = \frac{1}{(1-\hat{\beta})} S_{it} - \frac{\hat{\beta}}{(1-\hat{\beta})} A_{it}$$

We use equation (6) and the estimate of $\beta = 0.72$ (from the model in column (5) of Table 7) to infer estimates of desired alcohol content of wine for red wine and white wine from the New World and the Old World evaluated at the sample means of the data (as shown in panel a of Table 4). The results are summarized in Table 8.

[Table 8: *Actual, Reported, and Desired Alcohol Percentages by Country and Color of Wine*]

In Table 8, for red wine, white wine, and both red and white wine combined, country by country, we report the average actual (A) and average reported (S) alcohol percentage, and then the implied value for the "desired" alcohol percentage to report on the label (S^*) as implied by equation (6) and using a value for $\beta = 0.72$. Consider the last row of Table 8, representing the aggregate for the world as a whole. The average actual alcohol percentage for red wine (in the first column) was 13.47 percent but the reported alcohol percentage (in the next column) was

13.33 percent, from which we infer that the desired alcohol percentage (in the third column) was 12.98 percent—the reported percentage is between the actual and desired, closer to the actual reflecting the fact that $\beta = 0.72$ implies putting more weight on the actual alcohol content.

The same (third) column of Table 8 includes the counterpart estimates of the desired alcohol percentage for red wine by country of origin and for the New World and Old World aggregates of countries. We can see that the "desired" alcohol percentage for red wine ranges from a low of 12.52 percent for Canadian wine, just below 12.71 for French wine, up to a high of 13.66 percent for Australian wine, a full percentage point higher. Of course, these aggregates reflect aggregation across varietals and we might expect to see Australian Cabernet Sauvignon having a lower desired alcohol percentage than Australian Shiraz if we had data in such detail. Looking across the Table 8, the middle block of three columns of numbers refer to white wines, reporting the average actual, reported, and desired alcohol percentages, country by country. For the world as a whole, the average desired alcohol percentage for white wine is 12.48 percent (i.e. essentially 0.5 percentage points lower than for red wine), reflecting a range from a low of 12.04 percent for Canadian wine up to a high of 12.85 percent for New Zealand wine. Again, some of these differences may reflect differences in the varietal mix as well as differences that would be found holding the variety constant.[10]

4. Conclusion

In this paper we have used extensive data on the actual and reported alcohol content of wine from around the world to examine a number of questions that have been the subject of much conjecture but usually with limited empirical support. Our results indicate that the alcohol

[10] These results might understate the phenomenon in the broader global market to some extent, because the LCBO imposes relatively narrow tolerances for discrepancies between actual alcohol content and label claims.

content of wine varies systematically among countries, reflecting differences in climate, which we proxy using a measure of the heat index during the growing season for winegrapes, but also differences among varieties (lower for white than red wine varieties) and culture (lower for countries in the Old World of Europe than for the New World producers, mainly in the Southern hemisphere and the United States). The alcohol content of wine has been trending up significantly around the world, though at different rates in different places. Some, but not much, of this trend can be accounted for by trends in the heat index. The trend in alcohol that is not explained by the heat index is attributable to unobserved factors, such as other features of the climate or cultural responses to the market. While other measures of climate might have additional effects that we have not measured, our findings lead us to think that the rise in alcohol content of wine is primarily man-made.

Our analysis of the pattern of discrepancies between label claims and actual content suggests that in many places the rise in alcohol content of wine is a nuisance consequence of choices made in response to evolving demand for wine having more intense, riper flavors. Specifically, label claims appear to be biased towards a perceived norm, a "desired" alcohol percentage to report for a particular wine—red or white, New World or Old World—with the size of the bias depending on the extent to which the actual alcohol content differs from that norm. The implied values for these norms revealed by our analysis are approximately 12.8% alcohol (by volume) for Old World red, 12.3% alcohol for Old World white, 13.2% alcohol for New World red, and 12.7% alcohol for New World white. The alcohol content of much wine is high and rising relative to these norms, which can account for why the label claims on average understate the true alcohol content by about 0.39% alcohol for Old World wine (red or white) and about 0.45% for New World wine (red or white).

The work in this paper relates to several disparate strands of literature, including the more general literature on the economics of food labeling and labeling regulations (e.g., Golan et al., 2001), and other strands of marketing and behavioral economics as they relate to consumer responses to packaging and labeling as sources of information about product quality (e.g., Cheskin and Ward 1948; Woolfolk, Castellan, and Brooks 1983; Hine 1995; Dimara and Skuras, 2005; Costanigro, McCluskey, and Mittelhammer, 2007; Masson, Aurier, and d'Hauteville, 2008). It is of more direct relevance to work on hedonic pricing and other work related to consumer perceptions of the quality attributes of wine, as represented by information conveyed on the label and from other sources (e.g., see Gustafson 2011).

Many hedonic studies either did not include alcohol percentage as a relevant attribute (e.g., Oczkowksi, 1994, 2001; Dimara and Skouris 2005). Some attempted to quantify the effect of the alcohol content of the wine (as represented on the label) on price or other measures of consumer assessment of wine quality, such as jury grades, but for the most part the effect was not significant. For example, Combris, Lecocq, and Visser (1997), found that a dummy variable for "excess alcohol" had a statistically significant effect but nonetheless very small effect on jury grade in a subset of their sample (the measured coefficient was – 0.085 on a 20 point scale) though not in their full sample; see, also, Combris, Lecocq, and Visser (2000). One exception is Thrane (2004), who responded to a critique of the hedonic model by Unwin (1999) and presented a "stripped-down" model applied to wine prices in Norway. In that model the alcohol percentage did make a statistically significant contribution to the regression, with a positive coefficient that implied a relatively modest impact (1 percent more alcohol was associated with a 3 percent increase in price).

Our work suggests two points to be raised in interpreting this literature. First, given the relatively large and systematic errors in the alcohol percentage stated on wine labels, the evidence refers to consumers' willingness to pay for stated rather than actual alcohol percentages. Second, if consumers have a "desired" alcohol percentage in mind for a particular wine, we should not expect to see a simple linear relationship between willingness to pay and alcohol percentage; perhaps the models would be better specified in terms of the difference between the stated and desired alcohol percentage.

Finally, to return to our main finding, we have suggested that the substantial, pervasive, systematic errors in the stated alcohol percentage of wine are consistent with a model in which winemakers perceive that consumers demand wine with a stated alcohol content that is different from the actual alcohol content, and winemakers are willing to err in the direction of providing consumers with what they want. What remains to be resolved is why consumers choose to pay winemakers to lie to them. Further work could extend the findings from the analysis reported here to examine whether consumers really do pay premium prices for wine that more nearly conforms to the "desired" alcohol content norms we have estimated.

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Table 1. *Alcohol Content and Heat Index: Base Values, and Percentage Changes, by Color of Wine and Country*

Country	No. of Obs.	Alcohol Percentage by Volume, Average Annual % Change, and Trend Growth Rate: Red Wine: 1992 Average	Red Wine: Annual % Change	Red Wine: Trend Growth Rate	White Wine: 1992 Average	White Wine: Annual % Change	White Wine: Trend Growth Rate	Red and White Wines: 1992 Average	Red and White Wines: Annual % Change	Red and White Wines: Trend Growth Rate	1992-2007 Average Growing Season Temp.	Heat Index: Average Annual % Change	Heat Index: Trend Growth Rate
		% by vol.	*Percent per Year*		*% by vol.*	*Percent per Year*		*% by vol.*	*Percent per Year*		*°F*	*Percent per Year*	
Old World													
France	25,598	12.4	0.33	0.55	12.5	0.13	0.33	12.5	0.22	0.47	63.5	0.03	0.20
Italy	19,913	12.4	0.21	0.46	11.8	0.42	0.50	12.2	0.25	0.45	66.7	0.19	0.21
Spain	3,011	12.7	0.60	0.89	12.1	0.29	0.45	12.4	0.37	0.70	65.3	0.22	0.27
Portugal	2,337	12.3	0.31	0.94	11.9	0.41	0.69	12.2	0.28	0.84	69.2	-0.01	0.17
Total	*50,858*	*12.4*	*0.30*	*0.56*	*12.3*	*0.20*	*0.37*	*12.3*	*0.23*	*0.49*	*66.2*	*0.09*	*0.20*
New World													
Argentina	1,830	12.6	0.61	0.69	13.2	0.17	0.35	12.7	0.51	0.63	72.1	0.14	0.09
Australia	9,708	13.0	0.46	0.76	12.5	0.27	0.23	12.9	0.30	0.58	66.7	0.07	0.07
Canada	4,406	11.8	0.49	0.57	11.8	0.60	0.65	11.8	0.55	0.62	60.0	0.10	0.15
Chile	3,796	12.3	0.82	0.88	12.8	0.42	0.47	12.5	0.63	0.73	65.6	0.09	0.06
New Zealand	2,143	12.4	0.51	0.49	12.2	0.50	0.43	12.3	0.51	0.49	60.1	0.35	0.16
South Africa	3,400	12.7	0.59	1.03	12.7	0.23	0.56	12.7	0.38	0.85	67.8	0.04	-0.08
United States	16,545	13.5	0.12	0.56	13.4	0.08	0.32	13.4	0.09	0.49	65.4	-0.21	-0.10
Total	*41,828*	*13.1*	*0.31*	*0.63*	*12.9*	*0.22*	*0.34*	*13.0*	*0.25*	*0.54*	*65.1*	*0.09*	*0.03*
World	*92,686*	*12.7*	*0.30*	*0.62*	*12.5*	*0.20*	*0.36*	*12.65*	*0.23*	*0.53*	*65.5*	*0.09*	*0.11*

Table 2. *Alcohol Content and Heat Index: Base Values, and Percentage Changes, by Color of Wine and Region of Production*

Country	No. of Obs.	Alcohol Percentage by Volume, Average Annual % Change, and Trend Growth Rate									1992-2007 Average Growing Season Temp.	Heat Index	
		Red Wine			White Wine			Red and White Wines					
		1992 Average	Annual % Change	Trend Growth Rate	1992 Average	Annual % Change	Trend Growth Rate	1992 Average	Annual % Change	Trend Growth Rate		Average Annual % Change	Trend Growth Rate
		% by vol.	*Percent per Year*		*% by vol.*	*Percent per Year*		*% by vol.*	*Percent per Year*		*°F*	*Percent per Year*	
France													
Bordeaux	4,300	12.1	0.22	0.57	11.7	0.35	0.66	11.9	0.26	0.62	64.6	0.00	0.18
Burgundy	4,803	12.7	-0.12	0.18	13.0	-0.17	0.12	12.9	-0.16	0.15	60.9	0.00	0.21
Languedoc	1,542	12.1	0.68	0.80	12.0	0.58	0.46	12.0	0.64	0.70	67.7	0.02	0.12
Rhone	2,081	12.7	0.52	0.70	12.5	0.65	0.69	12.7	0.55	0.71	65.5	0.10	0.26
France Other	12,871	12.2	0.43	0.64	12.3	0.21	0.38	12.2	0.30	0.52	63.5	0.03	0.20
Canada													
British Columbia	794	11.6	0.96	1.17	12.0	0.86	1.06	11.9	0.89	1.15	58.9	-0.19	0.05
Ontario	3,530	11.8	0.47	0.45	11.7	0.54	0.55	11.8	0.51	0.50	60.8	0.52	0.26
Canada Other	82	--	--	0.13	12.0	0.75	0.45	12.0	0.40	0.29	60.0	0.10	0.15
U.S.													
California	14,547	13.5	0.16	0.56	13.4	0.10	0.30	13.5	0.11	0.48	70.2	-0.16	-0.18
Oregon	892	13.5	-0.39	0.38	13.8	0.12	0.23	13.6	-0.44	0.33	62.4	-0.32	-0.12
Washington	588	13.2	-0.02	0.63	12.8	0.14	0.75	13.1	0.03	0.78	63.7	-0.15	0.00
US Other	518	11.8	0.83	0.54	11.9	0.49	0.62	11.9	0.57	0.64	65.4	-0.21	-0.10
Italy													
Piedmont	1,230	13.5	-0.04	0.43	11.4	0.53	0.58	12.6	0.22	0.46	64.1	0.20	0.23
Tuscany	2,567	12.7	0.12	0.35	12.3	0.22	0.52	12.6	0.13	0.38	68.9	0.19	0.24
Veneto	1,403	11.8	0.40	0.58	11.5	0.35	0.43	11.6	0.34	0.49	67.1	0.11	0.16
Italy Other	14,713	12.4	0.22	0.48	11.8	0.43	0.51	12.2	0.26	0.47	66.7	0.19	0.21

Table 3: Regressions of Alcohol Percentage Against Trend and Temperature, 1992 to 2007

	Model					
Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Constant	12.72**	9.589**	10.41**	10.92**	10.87**	10.14**
Trend	0.0701**	0.0645**	0.0643**	0.0613**	0.0654**	0.0667**
Avg. Growing Temp		0.0486**	0.0384**	0.0364**	0.0280**	0.0393**
White Wine Dummy			-0.486**	-0.518**	-0.495**	-0.207**
Old World Dummy				-0.630**		
Argentina					0.295**	0.0291
Australia					0.547**	0.324**
Canada					-0.0887**	-0.171**
Chile					0.547**	0.150**
Italy					-0.165**	-0.194**
New Zealand					0.354**	0.325**
Portugal					-0.296**	-0.787**
South Africa					0.349**	-0.235**
Spain					0.230***	-0.0807**
United States					0.845**	0.730**
White x Trend						-0.0348**
Argentina x Trend						0.0171**
Australia x Trend						0.0220**
Canada x Trend						0.0144**
Chile x Trend						0.0411**
Italy x Trend						-0.000154
New Zealand x Trend						0.00904*
Portugal x Trend						0.0494**
South Africa x Trend						0.0624**
Spain x Trend						0.0337**
United States x Trend						0.0118**
R-squared	0.10	0.12	0.17	0.29	0.34	0.35
MSE	0.888	0.880	0.851	0.791	0.763	0.756

Notes:
Dependent variable is actual % alcohol. “France”, “Red Wine” and “France X Trend” are default categories.
** Significant at the 1% level, * significant at the 5% level, and - significant at the 10% level.
91, 432 Observations.

Table 4. Alcohol Reporting Error by Year, 1992-2007

Year	All Wine				Reported minus Actual Alcohol Percentage							
					New World				Old World			
	Obs.	Actual	Reported	Difference	Obs.	Red	Obs.	White	Obs.	Red	Obs.	White
	No.		*% by vol.*		No.	*% by vol.*	No.	*% by vol.*	No.	*% by vol.*	No.	*% by vol.*
Total	91,432	13.30	13.16	-0.13	26,881	-0.17	14,027	-0.17	35,348	-0.11	15,176	-0.09
1992	3,245	12.65	12.57	-0.07	865	-0.16	617	-0.19	953	0.03	810	-0.01
1993	4,224	12.68	12.62	-0.06	963	-0.16	715	-0.18	1,644	0.02	902	0.00
1994	4,424	12.79	12.66	-0.13	1,071	-0.18	871	-0.20	1,526	-0.09	956	-0.06
1995	4,990	12.86	12.69	-0.16	1,205	-0.19	898	-0.26	2,018	-0.12	869	-0.14
1996	4,805	12.90	12.73	-0.17	1,114	-0.18	913	-0.25	1,803	-0.13	975	-0.17
1997	4,175	12.99	12.82	-0.18	913	-0.22	862	-0.26	1,585	-0.11	815	-0.16
1998	3,668	13.23	13.09	-0.14	1,072	-0.12	427	-0.22	1,868	-0.12	301	-0.24
1999	5,681	13.36	13.24	-0.12	1,818	-0.14	541	-0.16	2,743	-0.11	579	-0.07
2000	7,825	13.29	13.18	-0.12	2,260	-0.13	982	-0.15	3,526	-0.11	1,057	-0.08
2001	7,741	13.47	13.34	-0.13	2,461	-0.18	889	-0.20	3,380	-0.10	1,011	-0.07
2002	6,828	13.48	13.34	-0.14	2,543	-0.18	1,026	-0.15	2,197	-0.11	1,062	-0.10
2003	7,784	13.64	13.47	-0.17	2,469	-0.21	921	-0.16	3,406	-0.16	988	-0.12
2004	8,478	13.65	13.50	-0.15	2,913	-0.18	1,149	-0.12	3,173	-0.16	1,243	-0.08
2005	8,345	13.69	13.54	-0.15	2,793	-0.21	1,240	-0.11	3,054	-0.13	1,258	-0.14
2006	6,269	13.50	13.39	-0.11	1,859	-0.13	1,241	-0.10	1,826	-0.09	1,343	-0.13
2007	2,950	13.12	13.10	-0.02	562	-0.08	735	-0.04	646	-0.03	1,007	0.03

Table 5. Alcohol Reporting Error by Country and Type of Wine

Year	All Wine				Reported Minus Actual Alcohol Percentage			
	Obs.	Actual	Reported	Difference	Obs.	Red	Obs.	White
	No.		*% by vol.*		No.	*% by vol.*	No.	*% by vol.*
Old World								
France	25,404	13.00	12.90	-0.10	16,938	-0.11	8,466	-0.10
Italy	19,806	12.97	12.88	-0.09	14,246	-0.09	5,560	-0.08
Spain	2,993	13.43	13.22	-0.21	2,465	-0.23	528	-0.14
Portugal	2,321	12.96	12.91	-0.05	1,699	-0.06	622	-0.03
Total	*50,524*	*13.01*	*12.91*	*-0.10*	*35,348*	*-0.11*	*15,176*	*-0.09*
New World								
Argentina	1,778	13.79	13.55	-0.24	1,437	-0.26	341	-0.16
Australia	9,617	13.74	13.65	-0.09	6,857	-0.09	2,760	-0.07
Canada	4,113	12.75	12.61	-0.13	2,097	-0.08	2,016	-0.18
Chile	3,744	13.71	13.43	-0.27	2,537	-0.28	1,207	-0.25
New Zealand	2,125	13.21	13.15	-0.06	802	-0.07	1,323	-0.06
South Africa	3,347	13.51	13.42	-0.09	2,164	-0.10	1,183	-0.06
United States	16,184	13.88	13.65	-0.23	10,987	-0.22	5,197	-0.25
Total	*40,908*	*13.65*	*13.48*	*-0.17*	*26,881*	*-0.17*	*14,027*	*-0.17*
World	*91,432*	*13.29*	*13.16*	*-0.13*	*62,229*	*-0.14*	*29,203*	*-0.13*

Table 6: Reported versus Actual Alcohol Content of Wine, by Color of Wine and Region of Production

	Observations		Reported Minus Actual Alcohol		Actual Alcohol		Reported Alcohol	
	% of Total	Number	Mean	t-stat.	Content	Std. Dev.	Content	Std. Dev.
			Alcohol by Vol.		*Alcohol by Vol.*		*Alcohol by Vol.*	
a. Total								
All Observations	*100*	*91,432*	*-0.13*	*-92.9*	*13.3*	*0.94*	*13.1*	*0.84*
Red	68.1	62,229	-0.13	-78.5	13.5	0.90	13.3	0.81
White	31.9	29,203	-0.13	-49.7	12.9	0.90	12.8	0.81
Old World Red	38.7	35,348	-0.11	-50.0	13.2	0.80	13.1	0.72
Old World White	16.6	15,176	-0.09	-27.7	12.6	0.80	12.5	0.72
New World Red	29.4	26,881	-0.17	-61.4	13.8	0.89	13.7	0.79
New World White	15.3	14,027	-0.17	-42.4	13.3	0.90	13.1	0.81
b. Under-reported Alcohol Content								
All Observations	*57.1*	*52,178*	*-0.42*	*-310.2*	*13.6*	*0.91*	*13.1*	*0.85*
Red	68.3	35,653	-0.42	-256.8	13.7	0.88	13.3	0.81
White	31.7	16,525	-0.41	-174.0	13.2	0.86	12.8	0.81
Old World Red	37.2	19,429	-0.39	-193.4	13.4	0.79	13.0	0.73
Old World White	15.7	8,188	-0.38	-127.4	12.9	0.78	12.5	0.73
New World Red	31.1	16,224	-0.45	-172.2	14.1	0.84	13.6	0.78
New World White	16.0	8,337	-0.45	-122.4	13.5	0.83	13.1	0.80
c. Over-reported Alcohol Content								
All Observations	*32.2*	*29,461*	*0.32*	*221.8*	*12.9*	*0.85*	*13.2*	*0.83*
Red	68.1	20,049	0.32	190.2	13.1	0.81	13.4	0.79
White	31.9	9,412	0.33	190.2	12.6	0.83	12.9	0.81
Old World Red	40.9	12,061	0.31	150.9	12.8	0.70	13.1	0.69
Old World White	17.7	5,229	0.33	93.0	12.3	0.72	12.6	0.70
New World Red	27.1	7,988	0.33	116.9	13.4	0.83	13.7	0.79
New World White	14.2	4,183	0.33	73.0	12.8	0.87	13.2	0.82
d. Correct Alcohol Content								
All Observations	*10.7*	*9,793*	*0.00*	*n/a*	*13.1*	*0.84*	*13.1*	*0.84*
Red	66.6	6,527	0.00	n/a	13.3	0.80	13.3	0.80
White	33.4	3,266	0.00	n/a	12.7	0.83	12.7	0.83
Old World Red	39.4	3,858	0.00	n/a	13.0	0.71	13.0	0.71
Old World White	18.0	1,759	0.00	n/a	12.5	0.72	12.5	0.72
New World Red	27.3	2,669	0.00	n/a	13.6	0.79	13.6	0.79
New World White	15.4	1,507	0.00	n/a	13.1	0.82	13.1	0.82

Note: "Correct Alcohol Content" has a 0.01 allowance in reporting error.
The t-statistic in the Reported Minus Actual Alcohol Column is resulted from a paired test of the difference in reported minus actual alcohol against zero. All are significantly different from zero at the one percent level (with the exception of the correct alcohol content case).

Table 7: Regressions of Reported Minus Actual Alcohol Percentage, by Country, 1992 to 2007

	Model				
Regressor	(1)	(2)	(3)	(4)	(5)
Constant	2.713**	2.209**	2.844**	3.331**	2.909**
Trend	0.0150**	0.0142**	0.0160**	0.0176**	0.0109**
Alcohol Level	-0.223**	-0.226**	-0.263**	-0.272**	-0.274**
Avg. Growing Temp		0.00842**	0.00732**	-1.70e-05	0.00802**
White Wine Dummy			-0.127**	-0.130**	-0.113**
Old World Dummy			-0.0990**		
Argentina				0.00953	-0.141**
Australia				0.189**	0.0460**
Canada				-0.0790**	-0.126**
Chile				-0.00404	-0.149**
Italy				-0.00642	-0.0602**
New Zealand				0.110**	0.0803**
Portugal				0.0207-	-0.181**
South Africa				0.142**	-0.0405*
Spain				-0.0315**	-0.0579**
United States				0.120**	0.00660
White x Trend					-0.00216**
Argentina x Trend					0.00953**
Australia x Trend					0.0142**
Canada x Trend					0.00947**
Chile x Trend					0.0150**
Italy x Trend					0.00357**
New Zealand x Trend					0.00734**
Portugal x Trend					0.0183**
South Africa x Trend					0.0180**
Spain x Trend					0.00217
United States x Trend					0.0130**
R-squared	0.21	0.21	0.24	0.25	0.25
MSE	0.386	0.385	0.379	0.376	0.375

Notes:
Dependent variable is the Difference (Reported – Actual alcohol percentage). France, Red and France x Trend are the default categories.
** Significant at the 1% level, * significant at the 5% level, and - significant at the 10% level.
91,432 Observations.

Table 8. Actual, Reported, and Desired Alcohol Percentages, by Country of Origin and Type of Wine

Country	Red Wine			White Wine			Red and White Wines		
	Mean Actual (A)	Mean Reported (S)	Mean Desired (S*)	Mean Actual (A)	Mean Reported (S)	Mean Desired (S*)	Mean Actual (A)	Mean Reported (S)	Mean Desired (S*)
Old World									
France	13.10	12.99	12.71	12.82	12.72	12.47	13.01	12.90	12.63
Italy	13.19	13.10	12.86	12.39	12.31	12.09	12.97	12.88	12.64
Spain	13.60	13.37	12.78	12.64	12.50	12.15	13.43	13.22	12.67
Portugal	13.19	13.13	12.99	12.33	12.31	12.24	12.96	12.91	12.79
Total	*13.18*	*13.07*	*12.79*	*12.64*	*12.55*	*12.31*	*13.01*	*12.91*	*12.64*
New World									
Argentina	13.90	13.64	12.96	13.34	13.18	12.78	13.79	13.55	12.93
Australia	14.00	13.91	13.66	13.07	13.00	12.82	13.74	13.65	13.42
Canada	12.80	12.72	12.52	12.69	12.51	12.04	12.75	12.62	12.28
Chile	13.83	13.54	12.81	13.45	13.2	12.55	13.71	13.43	12.73
New Zealand	13.45	13.38	13.20	13.07	13.01	12.85	13.21	13.15	12.98
South Africa	13.77	13.67	13.40	13.03	12.97	12.82	13.51	13.42	13.19
United States	13.99	13.77	13.21	13.66	13.41	12.78	13.88	13.65	13.07
Total	*13.85*	*13.67*	*13.23*	*13.27*	*13.10*	*12.67*	*13.65*	*13.48*	*13.04*
World	*13.47*	*13.33*	*12.98*	*12.94*	*12.81*	*12.48*	*13.16*	*13.30*	*13.64*

Appendix Table A-1. Regressions of Natural Logarithm of Alcohol Against Time, by Country, 1992 to 2007

	Red Wine				White Wine				Red & White Wines			
Country	Constant	Time	Adj R^2	N	Constant	Time	Adj R^2	N	Constant	Time	Adj R^2	N
Argentina	-11.12	0.0069	0.21	1,473	-4.44	0.0035	0.09	357	-9.96	0.0063	0.18	1,830
	(-15.8)	(19.6)			(-3.7)	(5.9)			(-15.6)	(19.7)		
Australia	-12.61	0.0076	0.21	6,916	-2.02	0.0023	0.02	2,792	-9.05	0.0058	0.10	9,708
	(-35.4)	(42.8)			(-3.3)	(7.6)			(-25.5)	(32.9)		
Canada	-8.82	0.0057	0.11	2,239	-10.52	0.0065	0.01	2,167	-9.81	0.0062	0.13	4,406
	(-12.6)	(16.2)			(-15.6)	(19.3)			(-20.4)	(25.6)		
Chile	-14.95	0.0088	0.38	2,572	-6.74	0.0047	0.18	1,224	-12.09	0.0073	0.30	3,796
	(-33.6)	(39.5)			(-11.7)	(16.2)			(-33.1)	(40.3)		
France	-8.46	0.0055	0.16	17,063	-4.04	0.0033	0.06	8,535	-6.82	0.0047	0.08	25,598
	(-43.0)	(56.0)			(-14.4)	(25.5)			(-41.5)	(57.1)		
Italy	-6.61	0.0046	0.09	14,332	-7.43	0.0050	0.15	5,581	-6.45	0.0045	0.08	19,913
	(-26.5)	(36.82)			(-23.3)	(31.1)			(-29.4)	(41.1)		
New Zealand	-7.20	0.0049	0.14	809	-6.07	0.0043	0.10	1,334	-7.18	0.0049	0.12	2,143
	(-8.5)	(11.5)			(-8.5)	(12.1)			(-12.8)	(17.4)		
Portugal	-16.28	0.0094	0.26	1,713	-11.27	0.0069	0.15	624	-14.23	0.0084	0.18	2,337
	(-21.3)	(24.67)			(-8.5)	(10.9)			(-19.3)	(22.8)		
South Africa	-18.08	0.0103	0.44	2,201	-8.71	0.0056	0.16	1,199	-14.41	0.0085	0.27	3,400
	(-36.5)	(41.8)			(-11.6)	(15.0)			(-30.4)	(35.9)		
Spain	-15.13	0.0089	0.28	2,480	-6.56	0.0045	0.09	531	-11.39	0.0070	0.15	3,011
	(-26.6)	(31.2)			(-5.2)	(7.2)			(-18.9)	(23.2)		
United States	-8.59	0.0056	0.15	11,189	-3.78	0.0032	0.06	5,356	-7.08	0.0049	0.11	16,545
	(-33.7)	(44.1)			(-10.7)	(18.1)			(-33.8)	(46.3)		

Note: *t*-statistics in parentheses.

Appendix Table A-2. Regressions of Logarithm of Alcohol Against Time, by Region, 1992 to 2007

	Red Wine				White Wine				Red & White Wines			
Region	Constant	Time	Adj R^2	N	Constant	Time	Adj R^2	N	Constant	Time	Adj R^2	N
Bordeaux	-8.83	0.0057	0.23	3,801	-10.67	0.0066	0.24	499	-9.82	0.0062	0.24	4,300
	(-25.8)	(33.2)			(-10.1)	(12.5)			(-29.0)	(36.5)		
Burgundy	-1.00	0.0018	0.04	2,670	0.08	0.0012	0.02	2,133	-0.51	0.0015	0.03	4,803
	(-3.1)	(11.0)			(0.2)	(6.7)			(-2.1)	(12.5)		
Languedoc	-13.43	0.0080	0.29	1,101	-6.67	0.0046	0.17	441	-11.49	0.0070	0.25	1,542
	(-17.7)	(21.1)			(-6.8)	(9.4)			(-18.5)	(22.7)		
Rhone	-11.36	0.0070	0.22	1,726	-11.28	0.0069	0.30	355	-11.58	0.0071	0.23	2,081
	(-17.9)	(22.0)			(-10.0)	(12.3)			(-20.4)	(25.0)		
France Other	-10.18	0.0064	0.17	7,765	-5.00	0.0038	0.06	5,106	-7.92	0.0052	0.11	12,871
	(-31.3)	(39.3)			(-12.5)	(18.8)			(-30.5)	(40.3)		
British Columbia	-20.78	0.0117	0.33	390	-18.73	0.0106	0.38	404	-20.33	0.0115	0.37	794
	(-12.4)	(14.0)			(-13.9)	(15.8)			(-19.1)	(21.6)		
Ontario	-6.51	0.0045	0.09	1,794	-8.56	0.0055	0.11	1,736	-7.54	0.0050	0.10	3,530
	(-9.5)	(13.2)			(-11.3)	(14.7)			(-14.8)	(19.8)		
Canada Other	-0.06	0.0013	-0.02	55	-6.38	0.0045	0.04	27	-3.34	0.0030	0.00	82
	(-0.01)	(0.3)			(-1.0)	(1.4)			(-0.6)	(1.0)		
California	-8.64	0.0056	0.15	9,877	-3.40	0.0030	0.06	4,670	-6.92	0.0048	0.12	14,547
	(-32.1)	(41.9)			(-9.6)	(16.9)			(-31.7)	(43.8)		
Oregon	-5.05	0.0038	0.10	596	-2.06	0.0023	0.03	296	-3.93	0.0032	0.07	892
	(-5.5)	(8.3)			(-1.3)	(2.9)			(-4.92)	(8.2)		
Washington	-10.06	0.0063	0.19	435	-12.48	0.0075	0.20	153	-13.06	0.0078	0.23	588
	(-8.0)	(10.1)			(-5.2)	(6.3)			(-11.0)	(13.2)		
US Other	-8.16	0.0054	0.07	281	-9.81	0.0062	0.12	237	-10.14	0.0064	0.11	518
	(-3.6)	(4.8)			(-4.5)	(5.7)			(-6.3)	(7.9)		
Piedmont	-5.99	0.0043	0.07	1,127	-9.14	0.0058	0.16	103	-6.69	0.0046	0.07	1,230
	(-6.6)	(9.5)			(-3.6)	(4.6)			(-6.7)	(9.3)		
Tuscany	-4.34	0.0035	0.06	2,313	-7.90	0.0052	0.11	254	-5.08	0.0038	.006	2,567
	(-7.6)	(12.2)			(-4.4)	(5.8)			(-8.8)	(13.3)		
Veneto	-9.14	0.0058	0.10	795	-6.17	0.0043	0.17	608	-7.37	0.0050	0.09	1,403
	(-7.4)	(9.5)			(-7.8)	(11.0)			(-8.9)	(11.9)		
Italy Other	-7.12	0.0048	0.10	10,097	-7.76	0.0051	0.16	4,616	-6.92	0.0047	0.09	14,713
	(-25.0)	(34.0)			(-22.2)	(29.4)			(-28.5)	(39.1)		

Note: *t*-statistics in parentheses.

Appendix Table A-3. *Regressions of Logarithm of Heat Index Against Time, 1992 to 2007*

Country	Constant	Time	Adj R^2	N
Argentina	2.48	0.0090	0.02	16
	(1.60)	(1.16)		
Australia	2.79	0.0007	-0.03	16
	(1.54)	(0.78)		
Canada	1.03	0.0015	0.12	16
	(0.60)	(1.76)		
Chile	3.06	0.0006	0.04	16
	(3.48)	(1.2)		
France	0.20	0.0020	0.29	16
	(0.14)	(2.66)		
Italy	-0.02	0.0021	0.39	16
	(-0.02)	(3.24)		
New Zealand	0.81	0.0016	0.12	16
	(0.44)	(1.77)		
Portugal	0.79	0.0017	0.15	16
	(0.43)	(1.9)		
South Africa	5.88	-0.0008	-0.01	16
	(3.39)	(-0.96)		
Spain	-1.22	0.0027	0.37	16
	(-0.70)	(3.11)		
United States	6.13	-0.0010	0.08	16
	(4.67)	(-1.51)		

Note: *t*-statistics in parentheses.

Appendix Table A-4. Regressions of Natural Logarithm of Heat Index Against Time, by Region, 1992 to 2007

Region	Constant	Time	Adj R^2	N
Bordeaux	0.56	0.0018	0.16	16
	(0.31)	(1.97)		
Burgundy	-0.05	0.0021	0.25	16
	(-0.03)	(2.43)		
Languedoc	1.80	0.0012	0.16	16
	(1.46)	(1.96)		
Rhone	-0.96	0.0026	0.38	16
	(-0.59)	(3.18)		
France Other	0.20	0.0020	0.29	16
	(0.14)	(2.66)		
British Columbia	3.11	0.0005	-0.06	16
	(1.14)	(0.36)		
Ontario	-1.01	0.0026	0.18	16
	(-0.41)	(2.08)		
Canada Other	1.03	0.0015	0.12	16
	(0.60)	(1.76)		
California	7.71	-0.018	0.24	16
	(5.16)	(-2.37)		
Oregon	6.44	-0.0012	0.07	16
	(4.03)	(-1.44)		
Washington	4.20	0.0000	-0.07	16
	(2.03)	(-0.02)		
United States Other	6.13	-0.0010	0.08	16
	(4.67)	(-1.51)		
Piedmont	-0.53	0.0023	0.45	16
	(-0.41)	(3.61)		
Tuscany	-0.60	0.0024	0.26	16
	(-0.31)	(2.48)		
Veneto	1.06	0.0016	0.19	16
	(0.72)	(2.11)		
Italy Other	-0.02	0.0021	0.39	16
	(-0.02)	(3.24)		

Note: *t*-statistics in parentheses.

Appendix Table A-5: Regressions of Logarithms of Alcohol Percentage against Trend and Temperature, by Country, 1992 to 2007

	Model					
Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Constant	2.541**	1.534**	1.760**	1.812**	1.906**	1.717**
Trend	0.00529**	0.00487**	0.00485**	0.00462**	0.00491**	0.00500**
LN Avg. Growing Temp		0.242**	0.191**	0.185**	0.152**	0.197**
White Wine Dummy			-0.0370**	-0.0394**	-0.0377**	-0.0178**
Old World Dummy				-0.0471**		
Argentina					0.0207**	0.00375
Australia					0.0395**	0.0251**
Canada					-0.00673**	-0.0147**
Chile					0.0406**	0.0128**
Italy					-0.0138**	-0.0165**
New Zealand					0.0283**	0.0255**
Portugal					-0.0248**	-0.0626**
South Africa					0.0250**	-0.0177**
Spain					0.0164**	-0.00535*
United States					0.0622**	0.0559**
White x Trend						-0.00241**
Argentina x Trend						0.00114**
Australia x Trend						0.00144**
Canada x Trend						0.00125**
Chile x Trend						0.00289**
Italy x Trend						9.60e-05
New Zealand x Trend						0.000704*
Portugal x Trend						0.00392**
South Africa x Trend						0.00462**
Spain x Trend						0.00238**
United States x Trend						0.000605**
R-squared	0.101	0.117	0.176	0.285	0.334	0.344
MSE	0.06705	0.06645	0.06421	0.05981	0.05769	0.05727

Notes:
Dependent variable is the natural logarithm of the Actual % Alcohol. “France”, “Red Wine” and “France x Trend” are the default categories.
** Significant at the 1% level, * significant at the 5% level, and - significant at the 10% level
91,432 Observations