Analyzing the risk of an illiquid asset
The case of fine wine

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Abstract

We use a unique and very deep database to examine the performance of wine investments during 2003–2014. Our results reveal that the returns stemming from those investments are important but can largely be explained by their exposure to common risk factors. As such and contradicting prior evidence, fine wines do not seem to offer abnormal returns. While explicitly accounting for non-synchronous trading, we indeed show that the market beta of wine is always positive and significant. Liquidity risk also turns out to be an essential determinant of wine returns. The fact that the liquidity factor, which is estimated on the basis of stock returns, can explain the returns on an exotic asset such as wine suggests that illiquidity is a common, cross-asset source of risk. Hence, this paper contributes to the literature on alternative investments and wine as an asset class and provides additional evidence regarding the nature of liquidity risk.

JEL Classification: Q14, G11, C50

Keywords: wine, alternative assets, liquidity

1. Introduction

During the last decade, considering fine wine as an investment category has become increasingly common. A variety of financial tools related to the wine market (e.g., wine indices and investment funds) have emerged and have attracted the interest of investors and alike. This growing popularity can be explained by the apparent high returns offered by fine wines, their low volatility, and—even more importantly—the low correlation they have maintained with other assets. Several recent research papers provide support for this belief. In particular, Sanning et al. (2008) show that investments in fine wines tend to generate positive abnormal returns, while Masset and Henderson (2010) further demonstrate that adding such investments to a portfolio improves its risk–return profile.

More generally, the academic literature has essentially focused on two complementary issues: determinants of wines prices (static perspective) and returns to an investment in wine (dynamic perspective). On the one hand, since the early nineties, the literature has acquired a precise understanding of the specificities of wine and their impact on prices. The influence of natural endowments, weather conditions during the growing season, the variety of grapes used in the blend, winemaking techniques, the producer's reputation, and expert rating, among others, have been examined in numerous studies.[1] On the other hand, the literature on wine price dynamics is less extensive and generally more recent.[2] While this literature has usually exploited the knowledge already gathered on wine prices and their determinants, it has typically not taken into account the very specificities of the wine market. In fact, the literature mostly proceeds to evaluate the performance of an investment in wine as if wine was just a "normal" asset traded on a "normal" market.[3] Unfortunately, wine is not such an asset. Indeed, wine is a special good that, similar to other so-called "emotional assets," does not offer cash flows and is very sensitive to human behavior. Moreover, the market for fine wines is structured in a complex manner and suffers from multiple sources of inefficiencies that make it rather illiquid.

The limitations from previous studies and, in particular, their failure to account for illiquidity cast doubt on the genuine performance of fine wine as an investment. In financial economics, illiquidity is increasingly recognized as a critical phenomenon that has important consequences for investors.[4] In particular, illiquidity may result in difficulties in properly estimating an asset's returns and volatility. Even worse, it may induce prices of illiquid assets to react with a delay compared with more liquid asset classes, thereby making a precise analysis of the relationship between illiquid investments and other asset classes difficult. Lastly, several works demonstrate that investors perceive illiquidity as a relevant source of risk and take it into account when developing their return expectations (see, e.g., Pastor and Stambaugh (2003) and Acharya and Pedersen (2005)). Therefore, the required rate of returns on assets that are sensitive to market-

[1] See, e.g., Byron and Ashenfelter (1995), Combris et al. (1997), Landon and Smith (1997), Combris et al. (2000), Jones and Storchmann (2001), Schamel and Anderson (2003), Ashenfelter (2008), and Oczkowski and Doucouliagos (2014).

[2] Two important early contributions are Krasker (1979) and Jaeger (1981). More recent contributions include Masset and Weisskopf (2010), Fogarty (2006), Fogarty (2010), Storchmann (2012), Masset and Weisskopf (2015), Faye et al. (2015), and Dimson et al. (2015).

[3] For instance, the two aforementioned studies of Sanning et al. (2008) and Masset and Henderson (2010) use a relatively limited dataset and apply conventional financial tools (e.g., asset pricing models and portfolio optimization procedures) without adjusting them to account for the lack of liquidity in the wine market.

[4] See Amihud et al. (2005) for a survey of the literature on illiquidity and its consequences on asset prices.

wide liquidity shocks may include a liquidity risk premium. These issues are yet to be considered within the context of fine wines.

In this paper, we devote particular attention to illiquidity and its effects. To develop a more precise quantification of the genuine performance potential that wine may offer, we proceed as follows. First, we exploit a novel and exhaustive dataset that contains the vast majority of transactions on the most sought-after wines in the world, namely the Bordeaux First Growths. Our dataset contains hammer prices from leading auction houses located all over the world and for the period 2003–2014. The wines considered in the present study represent a very significant part of the overall wine market in terms of number and value of transactions. For instance, they account for close to 80% of the market, according to Liv-ex.[5] To the best of our knowledge, we are the first to use such a deep dataset, which enables us to examine precisely the determinants of wine prices and, even more importantly, to estimate a very accurate wine index. Second, we use a methodology that acknowledges explicitly the lack of liquidity in the wine market. We follow Scholes and Williams (1977) and Dimson (1979) and estimate the "total" beta as the sum of both current and lagged market exposures. We also consider various sampling frequencies to study the relation between the wine market and the stock market. Data sampled at a lower frequency reduces the issue induced by non-synchronous changes in wine and stock prices. Third, we recognize the source of risk that illiquidity may represent for investors. Therefore, we add a liquidity risk premium to the conventional capital asset pricing model (CAPM). We follow the approach of Pastor and Stambaugh (2003) to develop this liquidity-augmented CAPM.

While prior research generally supports the claim that investments in fine wines are not very risky (thanks to their limited exposure to market risk) and generate positive abnormal returns, our results suggest a different story. We first show that fine wines are quite volatile, with an annualized volatility generally between 25% and 30%. The diversification potential that fine wines offer is also much lower than what has generally been reported to date in the literature. The correlation of fine wines with the S&P 500 and the MSCI World is close to 0.50–0.60. Even within a simple framework based on the CAPM, fine wines unequivocally trigger a positive and significant market risk premium. Nonetheless, fine wines retain a beta of less than 1.00 but the use of recent data combined with a methodology adapted to the analysis of an illiquid asset lead to a substantial decline in the estimated abnormal returns. That is, although the alpha is still positive, it loses its significance. Finally, we demonstrate that a substantial part of the returns to fine wines can be explained by a liquidity risk factor. The exposure of fine wines to this source of risk is positive and significant. Thus, the liquidity risk premium further reduces the alpha of fine wines, which becomes barely distinguishable from zero.

This paper contributes to the existing literature at two levels: the economics of collectibles and illiquidity and liquidity risk. First and foremost, our paper helps improve our comprehension of a particular type of collectible—fine wine—that has increased in importance during the last two decades. By their very nature (the existence of tens of thousands of bottles of the identical wine), they are the most actively traded collectibles. Therefore, the present study should provide relevant insights into how to address the risk features of less liquid collectibles, such as paintings, classic cars, or Chinese ceramics. We show that illiquidity is an important property of the market for fine wine and that it must be taken into account to obtain correct estimates of the volatility, correlation, and beta that fine wines maintain with other asset classes. Our results further indicate that wine investments are riskier than usually thought and that earning an abnormal return on the

[5] Liv-ex provides fine wine indices and valuation tools.

wine market is far more difficult than earning what investors and wine fund managers frequently suggest. This paper also advances our understanding of liquidity risk, which seems to be an essential determinant of the returns on the wine market. Given the illiquid nature of this collectible market, this result cannot be considered a complete surprise. However, that we use a liquidity risk premium whose calculation is based on the returns to stocks is important to note (Pastor and Stambaugh (2003)). Through a set of robustness tests, we assess the explanatory power of other common risk factors[6] and show that none of them appears as relevant in the context of wine investments. As such, our results suggest that market and liquidity risks affect various asset classes and are not specific to stocks. Thus, this paper also contributes to the developing literature on liquidity risk. Moreover and given that fine wines are among the most actively traded collectibles, that other collectibles are at least as sensitive to liquidity risk as fine wines seems highly probable.

The next section surveys the relevant literature on wine as an investment and on liquidity. Section 3 is dedicated to the presentation of our dataset and its specificities. In section 4, we expose the approach we use to construct wine indices and to assess the performance of an investment in wine. In section 5, we present and analyze the results. Section 6 concludes.

2. Wine investment and liquidity

2.1. Wine as an investment

Table 1 presents research on wine investments in chronological order. Apart from two contributions by Krasker (1979) and Jaeger (1981), both published in the Journal of Political Economy, the economy of fine wines has only truly started gaining the attention of academics since the 1990s.

< Insert Table 1 here >

Early contributions have generally focused on the determinants and the evolution of wine prices. Krasker (1979) arrives at the conclusion that red Bordeaux wines and Californian Cabernet Sauvignons have not significantly outperformed a riskless asset over the period 1973 to 1977. Jaeger (1981) considers similar wines but extends the period under investigation to encompass years 1969 to 1973. The results turn out being radically different as she observes that fine wines yielded on average 16.6% more than U.S. Treasury bills. Di Vittorio and Ginsburgh (1996) concentrate on the wines from the Médoc[7] and show that their prices have increased by close to 75% between 1981 and 1985, but have subsequently declined by 15% between 1986 and 1992. Byron and Ashenfelter (1995) find that the most famous Australian wine, Penfold's Grange, has achieved a real return of 3.9% p.a. over the period 1952–1980. Jones and Storchmann (2001) arrive at a fairly similar estimate of the real rate of return for Bordeaux wine (3% p.a. for the

[6] We consider the small-minus-big (SMB) and high-minus-low (HML) factors of Fama and French (1993), the momentum factor (MOM) of Carhart (1997), and the hedge fund benchmarks of Fung and Hsieh (2001, 2002, and 2004).

[7] Bordeaux can broadly be split into two sub-regions, the Médoc (on the left bank of the Gironde River) and the Libournais (on the right bank). The largest wine estates are in the Médoc.

period 1980–1994) but they also reveal that returns vary substantially from one estate to another. Burton and Jacobsen (2001) construct a Bordeaux index and track its performance from 1986 to 1996. Their index performs better than Treasury bonds (7.9% p.a. versus 5.8%) but it is clearly outperformed by stocks (13.5%).

Since the mid-2000s and following the increasing interest in wine as an asset class, research has started to investigate the specificities of this type of investment in more details. Fogarty (2006) considers the return *and* the risk imbedded in wine investments, and show that Australian wine and equity have exhibited a comparable risk-return profile during 1989–2000. Sanning et al. (2008) apply both the CAPM and the Fama-French (1993) three-factor model to analyze the returns to Bordeaux wines. Their results indicate that the latter have delivered abnormal returns (alpha) of 7.5–9.5% and have maintained a low exposure to systematic risk factors over the years 1996 to 2003. Masset and Henderson (2010) look at a longer period (1996–2007) and examine the role of wine within a portfolio containing various asset classes. Their results indicate that Bordeaux wines have features (attractive risk-return profile and low correlation with equities) that justify including them in an optimal portfolio. In a similar vein, Fogarty (2010) notes that Australian wines are only weakly correlated with other asset classes and could thus help improve the performance of an investor's portfolio. Masset and Weisskopf (2010) show evidence that, during 1996–2009, an index including wine from different French, Italian, and U.S. wine regions outperformed the U.S. stock market on a risk-adjusted basis. Wines also appear to have been particularly resilient during the economic crisis of 2001-2003 and the financial crisis of 2007-2009.

Recently, researchers have devoted their attention to more specific issues, such as the dynamics of wines from various regions and the performance of dedicated investment vehicles. Kourtis et al. (2012) demonstrate that the correlation among wines from France, Italy, Australia and Portugal remains sufficiently low to offer a significant diversification potential to investors aiming to invest in wines from different countries. Lucey and Devine (2015) argue that it is difficult for individual investors to replicate the performance of a well-diversified portfolio of wines and therefore suggest that indirect investments through wine funds could be a more appropriate solution for most investors. Masset and Weisskopf (2015) analyze the performance of wine funds and arrive at disappointing results for investors. Fund managers do not appear to be able to profit from market inefficiencies and do not manage to generate abnormal returns. Masset et al. (2016) examines the impact of the emergence of Hong-Kong as a major auction venue for fine wines. Their results uncover a price premium attached to wines sold in Hong-Kong. This premium is especially significant in 2008 when auction houses started operating on the Hong-Kong market. Since then it has progressively declined and, as of 2015, the prices in Hong-Kong remain only marginally higher than in the rest of the world.

A last contribution to the literature is due to Dimson et al. (2015), who examine the prices of the five most investable wines from Bordeaux from 1899 to 2012. This extremely long sample period allows them to investigate very precisely some of the peculiarities of wine investments. They show that wines deliver returns that are close to those from equities and higher than those from other emotional assets, such as art and stamps. Moreover, their results indicate that wines are in fact positively correlated with stocks. They follow the approach of Dimson (1979) and calculate an aggregate beta whose value is approximately 0.57 to 0.73 (depending on the period and sub-period chosen).

In summary, this section illustrates that it is difficult to precisely assess the potential of fine wine as an investment. Indeed, the results from the various studies contrast with one another and sometimes even conflict. Most of these discrepancies can be explained by differing research designs and are, thus, not directly comparable. These differences can be broadly classified into five categories: type of wines considered; period under investigation; methodology used to construct a wine portfolio or a wine index; financial models used to analyze the performance of such an investment; and type of prices (auction hammer prices, merchant prices) used to run the analysis.

2.2. Wine as an illiquid asset: Causes and consequences

Vast literature exists on illiquidity. Hereafter, we focus on aspects that bear a direct association with issues related to an investment in a collectible asset, such as wine. We start with a discussion of the sources of illiquidity and then examine their potential consequences.

A number of generic sources of illiquidity have been identified in the literature on financial economics. Notably, inappropriate market structure, a limited number of traders, lack of transparency, and others can result in low trading activity. A recent and comprehensive survey of the literature can be found in Amihud et al. (2012). In the case of wine, illiquidity is mostly caused by the way the market is organized and the very nature of the asset traded. Fine wines can be traded through a variety of channels and at multiple locations spread throughout the world. This absence of a single marketplace hinders the aggregation to a unique price for each wine (see, e.g., Cardebat et al. (2016)). Numerous market frictions worsen the situation. Apart from direct trading costs, one faces substantial shipping, storage, and insurance fees. Search costs can be considerable (some very rare bottles can be extremely difficult to find) and inventory risk is also significant because customer preferences may change rapidly. The market for fine wines remains rather opaque and suffers from important information asymmetries. That is, the various market players (producers, brokers, merchants, customers, investors, collectors) generally do not share the same information set. For instance, for buyers to gain access to precise information about remaining inventories held by producers and brokers is almost impossible. In some circumstances, collecting information about the quality of a specific wine may even be complicated, which is why experts, such as Robert Parker and James Suckling, are very influential regarding wine prices.[8]

Specificities of wine and, in particular, its intrinsic heterogeneity add complexity to the market and, thereby, further reduce its liquidity. Notably, the statement, "there is no great wine but only great bottles" is common. This sentence illustrates the fact that no two bottles are the same. A related issue is connected to the risk of trading counterfeit wine.[9] Its nature also makes wine very prone to human biases (irrational behavior). In particular, its valuation is complex and highly subjective because it does not deliver any cash flow. Finally, the quantity of each wine available for trading is limited because of limited production. Moreover, most wine buyers purchase wine for consumption purposes and not for investment; therefore, each wine has a rather low "free-float" because many buyers simply hold the bottles in their cellars until eventually drinking them.

A lack of liquidity directly affects asset returns and their statistical features. Many wines do not trade on a regular basis and, hence, their prices often remain constant for several weeks. Thus,

[8] See Cardebat et al. (2014) and Masset et al. (2015) for an analysis of wine experts' ratings and their influence on prices.
[9] See, for example, the recent scandal surrounding Rudy Kurniawan.

infrequent trading activity generates stale prices and, if not properly taken into account, can further result in underestimation of volatility and spurious positive autocorrelation even at long lags. Fine wines, similar to other illiquid assets, also tend to react much less rapidly to new information than stocks or bonds. This non-synchronicity needs to be taken into account; otherwise, the cross-relationship of wine with other asset classes and, in particular, its beta is likely to be severely underestimated.

Illiquidity may also result in substantial direct costs (due in particular to the bid–ask spread) and price-impact costs (due, for instance, to wine funds having to unwind some of their positions) for investors. Consequently, investors expect compensation for investing in illiquid assets. In the context of stocks, Amihud and Mendelson (1986) indeed show that the relation between illiquidity and return is positive and concave. This latter feature suggests that investors with longer investment horizons are more likely to invest in less liquid stocks. Using two measures of liquidity (the bid–ask spread and a measure of price-impact costs), Brennan and Subrahmanyam (1996) also find a strong positive relation between liquidity costs and average returns. Datar et al. (1998) and Brennan et al. (1998) arrive at a similar conclusion using, respectively, the turnover rate (defined as the ratio of trading volume to the number of shares outstanding) of NYSE stocks and the trading volume of NYSE, AMEX, and Nasdaq stocks. Bonds display a similar pattern, with less liquid bonds achieving higher returns. Amihud and Mendelson (1991) compare Treasury bills and notes with less than six months to maturity and show that the yields on the bills are on average 0.43% lower than on the notes. Both instruments are rigorously similar but the bills are more liquid than the notes. In a similar vein, Chen et al. (2007) demonstrate that less liquid corporate bonds have higher yields. In a survey paper, Amihud and Mendelson (2008) point out that companies that manage to increase the liquidity of their own debt and equity securities see their market value increasing (and the corresponding required rate of return decreasing). An implication of these results is that a sudden change in liquidity might actually have a substantial impact on asset prices. As noted by Amihud (2002), "when market liquidity falls, investors anticipate that liquidity costs will remain high for a while because of the persistence of illiquidity; and higher expected liquidity costs should cause expected returns to rise and stock prices to fall."

Apart from direct and indirect costs, illiquidity may also result in a "liquidity risk premium." Pastor and Stambaugh (2003) and Acharya and Pedersen (2005) were among the first to propose a liquidity-augmented asset pricing model. Pastor and Stambaugh (2003) argue that some investors prefer to hold assets that are less sensitive to aggregate liquidity. Thus, assets that are more sensitive to liquidity shocks are expected to trigger a liquidity risk premium. Based on these premises, Pastor and Stambaugh (2003) estimate a systematic liquidity risk factor that they then include in the standard CAPM. Acharya and Pedersen (2005) develop a four-beta asset pricing model, in which the first beta is the conventional beta from the CAPM and the other three betas are related to the covariance between stock liquidity and market liquidity, the covariance between a stock's return and market liquidity, and the covariance between a stock's liquidity and market returns. More recently, Amihud (2014) proposes an extension of the Carhart (1997) four factor model that includes a liquidity risk factor.

Amihud et al. (2012) show that the illiquidity premium is time-varying because it typically increases in periods of market stress, thereby suggesting that liquidity is more valuable during such periods. Acharya and Viswanathan (2011) argue that falling prices put financial constraints on financial intermediaries (they have to refinance their short-term debt), which have no choice but to liquidate part of their financial positions. The liquidity premium seems also affected by credit conditions. To account for those patterns, Amihud (2014) proposes a conditional version

of his model, in which he uses the BAA–AAA spread as a conditioning variable for the illiquidity premium. Additionally, liquidity must be noted to generally correlate with volatility, which is why Amihud et al. (2012) base their inferences on portfolios sorted on the basis of both liquidity and volatility. In the context of bonds, Acharya et al. (2013) show that the influence of liquidity on yields depends on economic conditions and the category of bonds considered. Liquidity shocks seem to have an effect only during periods of economic uncertainty, and this effect is negative on junk bonds (i.e., their prices decline) but positive on investment-grade bonds (i.e., their prices increase). This occurrence may indicate the presence of a "flight-to-liquidity" or "flight-to-quality" phenomenon.

This discussion indicates that considering both a large database to deal with the issues induced by the low degree of liquidity of the wine market and using appropriate methods to estimate reliable indices and to assess precisely their features in terms of market and liquidity risk are essential. Thus, in the next two sections, we present our dataset (section 4) and then explain the research design followed by this study (section 5).

3. Data

Our sample contains hammer prices for the five "First Growth" wines from the Médoc and Graves regions plus Château Mission Haut-Brion,[10] the four "First Growth A" from Saint-Emilion, the only "Superior First Growth" from Sauternes, and the three best wines from Pomerol (see table 2 for details).[11] These wines are amongst the finest and most sought after in the world. Collectors, investors, and wine funds in particular invest a substantial portion of their portfolio into these wines. According to Liv-ex, they account for close to 80% of the market for fine wines.[12] We consider only vintages from 1945 to 2010 because older vintages may suffer from an "antique effect" (see Krasker (1979) and Jaeger (1981)).[13] The use of auction hammer prices ensures that the prices recorded correspond to genuine transactions.[14] Our dataset includes almost *all* transactions involving the fourteen wines presented above and is thereby much deeper than the samples used in previous research. The large number of observations is crucial as it enables us to come up with very precise indices.

3.1. Presentation of the dataset

We have collected hammer prices from all major auction houses in the world (Acker Merrall & Condit, Bonham's, Christie's, Edward Roberts, Hart Davis Hart, Morell's, Sotheby's, and

[10] While not officially classified as First Growth, this wine is considered to achieve the same level of quality as its neighbor, Château Haut-Brion, which is ranked as First Growth.

[11] The terms "First Growth," "First Growth A," and "Superior First Growth" refer to wines that have been ranked at the top of the classification of Bordeaux wines. In the Médoc and Graves regions, and in Sauternes, this classification has remained almost similar since 1855 (only Château Mouton Rothschild was upgraded in 1973). In Saint-Emilion, the classification is updated every 10 years (in 2012, Angélus and Pavie have been upgraded from "First Growth B" to "First Growth A"). In Pomerol, no official classification exists but the hierarchy is nevertheless relatively clear, with Pétrus, Lafleur, and Le Pin widely considered as the best wines from this appellation.

[12] http://www.blog.liv-ex.com/2014/07/talking-trade-18-24-july.html.

[13] Very old wines have different characteristics than young wines. Notably, they tend to be more difficult to taste and appreciate. Moreover, when buying such a wine, a significant probability exists that it is no longer drinkable. As such, those wines attract a rather different clientele than younger wines.

[14] Using listed prices from merchants can lead to substantial biases for two reasons. First, they do not necessarily correspond to effective transaction prices. Second, the number of bottles available at a given price is generally not precisely known.

Zachy's).[15] We discard mixed lots and only consider lots that consist of identical wines (same château and vintage). Our final dataset contains observations for 634 unique château–vintage couples and consists of 152,484 lots representing a total of 1,382,601 bottles (only 750 ml) sold between 2003 and 2014.

It is necessary to distinguish each vintage for each château because the quality can vary strongly from one vintage to another. For example, Château Mouton Rothschild 2000 and Château Mouton Rothschild 2001, although produced by the same owner, are two different wines that sell at different prices. Actually, the average price in 2014 for a bottle of Mouton Rothschild 2000 was close to US$1,200, while the price of the 2001 vintage was less than US$400. In order to account for such differences in quality, we use "Parker scores", which, in this specific example, are respectively 96 and 89 points. Robert Parker is regarded as the most influential wine expert in the world (see, e.g., Cardebat et al. (2014) and Masset et al. (2015)). His scores are reported on a scale from 50 to 100 points. We obtain Parker scores for 496 wines (representing 97% of all transactions) which have an average Parker score of 94.5. For each lot, we also have information on the number of bottles auctioned. Ceteris paribus, the higher the number of bottles in a lot, the lower the selling price should be. A lot consists of an average of nine bottles, but some lots have up to 600 bottles and a few have just one bottle. If the bottles are in their original wooden cases (henceforth, OWC), they generally sell at a premium. The presence of the OWC lowers the uncertainty over the storage conditions of the wine and reduces the risk of buying counterfeits. In our dataset, approximately 57% of all lots auctioned consist of cases of 12 bottles and 12% of cases of six bottles.

Data on stock markets, exchange rates, and interest rates are from ThomsonReuters Datastream. We also collected data on various risk factors, including the Fama and French (1993) small-minus-big (SMB) and high-minus-low (HML) factors, the Carhart (1997) momentum factor (MOM),[16] the Pastor and Stambaugh (2003) liquidity factor,[17] and the Fung and Hsieh (2001) trend-following risk factors.[18]

3.2. Descriptive statistics

In Table 2, we report the average price (Panel A) and information on the trading activity (Panel B) per Château and per year. As is apparent from panel A, wines from the same appellation trade at prices that are in the same order of magnitude. This price homogeneity is stronger in the appellations from the left bank of the Gironde (Médoc and Graves) than elsewhere in Bordeaux. In Saint-Emilion, the prices of Angélus and Pavie, both recently upgraded (in 2012) have yet to catch up with the two historic First Growths A (Ausone and Cheval Blanc) from this appellation. Although wines from Pomerol and, more specifically, Pétrus and Le Pin, are not officially ranked as First Growths, they nevertheless tend to be the most expensive in the entire Bordeaux area. This observation can be attributed to a rarity effect as wines from Pomerol are much scarcer (with productions from 6,000 to no more than 30,000 bottles per year) than their counterparts from Saint-Emilion (70,000 to 120,000) and the left bank (70,000 to 300,000).[19]

[15] The hammer price includes the relevant buyers' premium but is exclusive of sales taxes or VAT.
[16] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.
[17] http://faculty.chicagobooth.edu/lubos.pastor/research/liq_data_1962_2014.txt.
[18] http://faculty.fuqua.duke.edu/~dah7/DataLibrary/TF-FAC.xls.
[19] These figures are approximations based on various sources. Moreover, note that production can vary dramatically from one year to another depending on weather conditions.

< Insert Table 2 here >

Most wines have experienced a strong increase in price between 2003 and 2011, which can be explained by a string of great vintages (2005, 2009, and 2010) and the massive arrival of new customers from BRIC countries and, in particular, China. Since mid-2011, prices have adjusted. These patterns are especially pronounced for Lafite Rothschild, whose prices exhibited a bubble-like dynamic, with an increase of 300% to 400% between 2005 and 2011 followed by a 40% decline in 2012–2014. Ausone has also experienced a substantial increase in price during the last fifteen years, a phenomenon that can be explained by the dramatic improvement in quality this estate has experienced since the 1980s. Indeed, the average Parker score for Ausone has progressed from 82.4 in the eighties to 89.8 in the nineties and 97.3 in the first decade of the new century. Angélus and Pavie have steadily increased since 2003 and more rapidly since their upgrade to First Growth A status in 2012.

Panel B reports the average number of trades per month and the average trade size (i.e., number of bottles per trade) for each wine. The average number of trades is directly related to trading probability. Therefore, this measure clearly resembles the liquidity proxy used by Liu (2006), who takes into account *non*-trading probability and turnover rate. In general, wines from the Médoc and, more particularly, Mouton-Rothschild and Lafite-Rothschild are the most liquid. Pétrus and Cheval-Blanc are also traded on a regular basis but the other wines from Saint-Emilion and Pomerol tend to show up at auctions much less frequently. The higher liquidity of wines from the Médoc and Graves regions is not surprising given that these estates produce more bottles than their counterparts. Panel B also illustrates the tremendous increase in trading activity that the wine market has experienced between 2003 and 2011. Since 2011, trading activity, although still significantly higher than its 2003 level, has nevertheless substantially decreased. This pattern is especially pronounced for Lafite Rothschild. On the other hand, trading size has remained fairly stable. Wines from Pomerol and Yquem are generally traded in smaller lots, often close to six bottles, which is not surprising because these wines typically sell in cases of six bottles while the other First Growths more frequently come in cases of 12 bottles.

< Insert Table 3 here >

Table 3 shows the average price and trading activity per vintage calculated during 2014.[20] The trading activity figures demonstrate that some vintages, such as 1982, 1990, or 2000, clearly attract more interest from collectors and investors than others, such as 1981, 1991, or 1999. This pattern is mostly due to differences in quality, as evidenced by the average Parker scores for the various wines in these vintages (94.6, 95.9, and 97.9 for 1982, 1990, and 2000; and "only" 86.9, 86.7, and 93.1 for 1981, 1991, and 1999). Other great vintages include 1945 (great and highly symbolic as it corresponds to the end of WWII), 1959, 1961, and—more recently—2005, 2009, and 2010. Of course, vintages deemed superior in quality trigger higher prices. For instance, the average price for a bottle of 1982 in 2014 was slightly lower than US$1,600, while First Growths from 1981 traded on average close to US$500.

[20] Similar statistics for years 2003 to 2013 are available from the authors on request.

< Insert Table 4 here >

Table 4 shows the turnover achieved by each auction house and at each location. Generalists, such as Christie's and Sotheby's, dominate the wine auction market, although some specialized auction companies are not far behind these two giants. In particular, Acker Merrall & Condit, Hart Davis Hart, and Zachy's account for at least 10% to 15% of the overall turnover achieved at wine auctions. Other auction companies are much smaller. Most trades take place at one of the three main locations of Hong Kong, London, and New York. Hong Kong has emerged as a major venue for wine auctions in 2008 and now accounts for approximately 40% of the worldwide trading volume.

4. Methodology

In this section, we first explain how we estimate a series of wine indices whose purpose is to reflect the performance of a typical wine investor's portfolio. In a second step, we examine how to assess the risk–return features of a wine investment and propose two techniques to overcome the problem induced by the slow adjustment of wine prices to new information. We then analyze whether fine wines trigger an illiquidity risk premium. In a final step, we propose two hypotheses that are tested in section 5.

4.1. Index construction

A variety of methods can be used to estimate wine indices. In practice, index providers, such as Liv-ex (in the U.K.) or Idealwine (in France), calculate their indices on the basis of the weighted average price of their components. The simplicity of this approach makes it convenient from a practical viewpoint, but its inability to account for the illiquidity of the wine market makes it prone to biases. In academic research, most authors favor the hedonic regression (henceforth, HR) (see, e.g., Jones and Storchmann (2001) and Fogarty (2006)) or the repeat-sales regression approach (RSR) (see, e.g., Burton and Jacobsen (2001) and Dimson et al. (2015)).[21] These two methods have the ability to deal with two key specificities of the wine market: the heterogeneity of the "assets" traded, and the overall lack of liquidity. The main difference between the HR and RSR approaches lies in the fact that the former aims to explicitly model wine *prices*, while the latter only considers the *returns* between repeated transactions of the same wine. As such, the main advantage of the RSR over the HR is that it does not require the explicit identification of all potential price determinants. However, this advantage comes at a cost: as this approach only uses repeated transactions, a substantial number of observations might be lost. In this paper, we opt for the HR approach as it exploits all observations and allows control of the influence on the hammer price from a variety of wine and transaction-specific attributes.[22] The nature of our sample, which is composed of a limited number of wines that trade on a regular basis, ensures that the number of observations per explanatory variable is high, thereby leading to precise and robust inferences.

[21] Other methods encountered are the hybrid method (Fogarty and Jones (2011)) and the average or winsorized average of returns (Sanning et al. (2008) and Masset and Henderson (2010)).
[22] As a robustness test, we also estimate an index using the RSR approach. The results remain qualitatively similar (see section 5.5 for more details).

The HR was initially proposed by Rosen (1974) and has often been applied in the context of assets that trade only infrequently, such as real estate (e.g., Campbell et al. (2011)) or art works (e.g., Chanel et al. (1996)). This approach rests on the assumption that the price of a bottle of wine depends on its attributes (e.g., varietal used, vintage, reputation) and the implicit value attached to each of them. The functional form of a hedonic regression is in a linear semi-log form:[23]

$$p_i = \beta_0 + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_i \quad [1]$$

where p_i is the natural logarithm of the price of lot $i = \{1,2,\dots,N\}$; x_{ij} and contains information on the attributes of lot i and the regression coefficients β_j, $j = \{1,2,\dots,J\}$ correspond to the implicit value attached to each specific wine attribute. These attributes may include explanatory variables that are specific to the wine auctioned, such as producer name, vintage, and expert score, as well as distinctive variables, such as the presence of an original wooden case or the number of bottles in a lot. Equation [1] is appropriate for studying the price mechanics at a particular moment in time. If the sample under investigation includes prices recorded at different moments, equation [1] can be further extended to account for this feature:

$$p_i = \beta_0 + \sum_{j=1}^{J} \beta_j x_{ij} + \sum_{t=1}^{T} \theta_t d_{it} + \varepsilon_i \quad [2]$$

where d_{it} is a dummy variable taking the value 1 if wine i has been traded in period t and 0 otherwise. The coefficients associated with this matrix, pooled into vector θ, correspond to the natural logarithms of the index levels at the various dates $t = (1,\dots,T)$. Thus, a wine price index can be constructed on the basis of the exponential of these coefficients, $\exp(\hat{\theta})$, where $\hat{\theta}$ are the fitted regression coefficients from [2].

4.2. Specification used in this paper

We consider three specifications based on equation [2], which include three different sets of explanatory variables. The first specification focuses on the effect of age and vintage quality on wine price. This specification appears in two slightly different forms: the 1a) version only includes age, while the 1b) version also controls for the interaction effect of age and the quality of a specific vintage. The second specification is more detailed because it assesses the value attached to each particular vintage, from 1945 to 2010. Finally, the third specification is used to account for a potential "Lafite Rothschild effect." An abundance of newspaper and magazine articles suggest that the prices of Lafite Rothschild have displayed a bubble-like pattern since 2008. Table 5 contains the list of variables used in each specification. Hereafter, we provide details and explanations for each variable.

< Insert Table 5 here >

[23] The semi-log form is the most frequently encountered specification for hedonic regressions (see, e.g., Oczkowski and Doucouliagos (2014)).

A. Variables specific to the wine auctioned: We consider variables such as château, vintage, quality, age, and expert ratings. The purpose of these variables is to control for the various sources of price differences among the wines that have been auctioned. For instance, it is well known that weather conditions in the Bordeaux region can vary drastically from one vintage to another, thereby leading to important price differences (Cardebat et al. (2014)). In a similar vein, some châteaux may benefit from better *terroir* (natural endowments) or enjoy a stronger reputation, resulting in higher prices (see, e.g., Malter (2014)). To investigate the existence of a specific trend affecting the prices of Lafite-Rothschild wines, we further add in the third specification a series of time dummies specific to Lafite-Rothschild.[24] We use Parker scores to model the relation between quality and price. As this relation might be non-linear, with high-scoring wines selling for particularly high prices, we also include squared Parker scores in our specification. Finally, we consider the age of a wine as a determinant of its price. One expects a positive relation between age and price due to increasing scarcity and improvement in quality throughout the aging process. The age variable must be noted as being collinear with the vintage and time-of-sale dummies. As such, we use the age variable only in the first specification, which does not include vintage dummies. We also add a variable to account for the interaction between vintage quality and age because a wine from an excellent vintage is likely to benefit more from the aging process than a wine from an average vintage. We use five dummy variables to account for the overall quality of a vintage (from great to poor).[25]

B. Variables specific to a particular transaction: Apart from the wine itself, several features of a particular auction may affect hammer prices. For instance, specific tax regimes, fee structures, or shipping costs may lead to substantial price differences between two auction houses and locations (Cardebat et al. (2016)). Moreover, some auction houses enjoy a better reputation than others. To control for such effects, we include auction house and location dummies in the regression. To control for a quantity discount, i.e., a negative relation between the number of bottles auctioned and the hammer price, we add a variable defined as the number of bottles in a particular lot. Wines still in their OWC are likely to trade at a premium because the presence of the original case may reduce the risk of buying a counterfeit. Therefore, we include an additional dummy variable that takes the value 1 if the auctioned wine comes in its OWC and 0 otherwise. We consider two dummy variables to distinguish between OWCs of six and 12 bottles.

4.3. Performance and risk analysis

4.3.1. Delayed reaction

Illiquidity manifests itself in low trading activity characterized by a limited number of trades. The methodology previously presented aims to extract as much information as possible from observed prices to determine a precise estimation of wine index levels. However, this lack of liquidity may also result in delayed reactions of the wine market to economic and financial news, which may lead to an underestimation of the contemporaneous relation between fine wines and other assets. To analyze the performance and, more specifically, the risk features of an

[24] As a preliminary and exploratory step, we have also run the hedonic regression using data from all wine producers except Lafite Rothschild. The results effectively suggest that the evolution of Lafite Rothschild prices differs from the other First Growths.

[25] The quality of each vintage is estimated on the basis of two complementary sources: Idealwine (www.idealwine.com) and Robert Parker's vintage chart (http://www.erobertparker.com).

investment in fine wines, we resort to the Capital Asset Pricing Model (CAPM) and make some adjustments to the classical approach to account for the illiquidity of the wine market.

The classical CAPM (Sharpe (1964), Lintner (1965), and Mossin (1966)) decomposes observed excess returns into three parts: a constant (the so-called alpha or the Jensen (1968) alpha), a risk-premium, and a residual, as follows:

$$R_{w,t} - r_{f,t} = \alpha_w + \beta_w\left(R_{M,t} - r_{f,t}\right) + \varepsilon_t \quad [3]$$

$R_{w,t}$, $R_{M,t}$, and $r_{f,t}$ are the return on the wine index, the return on a reference stock market index, and the risk-free rate at time t. Beta (β_w) captures the systematic risk involved in an investment in fine wine, while alpha (α_w) provides an estimate of its abnormal return. Alpha has gained particular status in the context of alternative investments. This kind of investment indeed aims at generating returns that do not depend on market conditions; such returns are thus considered abnormal and can be quantified by the alpha.

To account for a potential lagged response of the wine market to changes in the economic and financial conditions, we proceed as follows. We first estimate equation [3] using both monthly and quarterly data. Delayed reaction is likely to play a substantially lesser role when low-frequency data are used to estimate the beta. A second approach involves adding lagged market returns to specification [3]. This approach, initially suggested by Scholes and Williams (1977) and Dimson (1979), has been applied in Dimson and Spaenjers (2011) and Dimson et al. (2015) in the context of collectible stamps and fine wines, respectively.

$$R_{w,t} - r_{f,t} = \alpha_w + \sum_{j=0}^{J} \beta_{w,j}\left(R_{M,t-j} - r_{f,t}\right) + \varepsilon \quad [4]$$

The *total* beta of a wine w can then be obtained by summing contemporaneous and lagged beta estimates, i.e., $\beta_w = \sum_{j=0}^{J} \beta_{w,j}$, with J representing the number of lagged market returns to be used in the estimation.

4.3.2. Illiquidity risk

As discussed in the literature review, illiquidity is a complex phenomenon that does not only affect the statistical properties of asset returns but also the cost of trading those assets and, more importantly, their risk. Liquidity shocks may impede investors' ability to trade and may thereby considerably impact their utility. Illiquid assets, such as fine wines and other collectibles, are likely to be particularly sensitive to this source of risk. Therefore, we use the Pastor and Stambaugh (2003) liquidity-augmented version of the CAPM to determine whether investors are rewarded by a liquidity risk premium when they invest in fine wine. The Pastor and Stambaugh liquidity factor is estimated using an approach that is conceptually close to the one that Fama and French (1992, 1993) proposed to construct their SMB and HML factors. Pastor and Stambaugh (2003) first estimate a non-traded liquidity factor (denoted L_t) that tracks the innovations in the level of liquidity at the market level. They then form portfolios on the basis of the sensitivity of the various stocks to L_t. Finally, they subtract the returns on the portfolio containing the stocks that are the least sensitive to liquidity from the one with the most sensitive stocks. The difference in returns between these two portfolios corresponds to the traded liquidity factor, LIQ_t. This factor can then be added to the conventional CAPM, thereby leading to the following model:

$$R_{w,t} - r_{f,t} = \alpha_w + \beta_w\left(R_{M,t} - r_{f,t}\right) + \gamma_w LIQ_t + \varepsilon_t. \quad [5]$$

LIQ_t is the liquidity risk factor and γ_w quantifies the exposure of fine wine to this source of risk. Equation [5] can be extended by adding lagged realizations of the stock market and liquidity premia:

$$R_{w,t} - r_{f,t} = \alpha_w + \sum_{j=0}^{J} \beta_{w,j}\left(R_{M,t-j} - r_{f,t}\right) + \sum_{k=0}^{K} \gamma_{w,k} LIQ_{t-k} + \varepsilon_t. \quad [6]$$

where J and K are the number of lagged market returns and lagged realizations of the liquidity factor used in the estimation.

4.4. Hypotheses

Following the discussion from the previous sections and in particular the analysis of the wine market in terms of organization and liquidity, we can now derive two hypotheses. Models [3] and [4] are used to test the first hypothesis, and models [5] and [6] are used to test the second hypothesis.

Hypothesis 1: The conventional beta is underestimated because of a delayed reaction of the wine market to changes in economic and financial conditions.

This hypothesis is further split into two sub-hypotheses.

- **Hypothesis 1a:** The beta increases when data sampled at lower frequencies are used.
  To test this hypothesis, we compare the beta obtained on the basis of model [3] for monthly and quarterly data. To test whether the difference between frequencies is significant, we use a bootstrapping procedure. That is, we randomly rearrange the sequence of monthly returns on the wine index and the reference stock market index. We then aggregate these shuffled monthly returns to calculate quarterly returns. We use these rearranged time-series of returns and calculate simulated betas. Finally, we compare the original quarterly betas to their simulated counterparts and determine whether they are statistically significant. We set the number of simulations to 1,000,000.
- **Hypothesis 1b:** The total beta is significantly different from the conventional beta.
  If the wine market follows financial markets with a delay of a few months, one may expect the lagged beta(s) from model [4] to be different from 0. As such, this hypothesis can be tested by examining whether $\beta_{w,j}$ is significantly different from 0 for $j > 0$. This examination can be achieved by observing the T-stat attached to $\beta_{w,j}$ for $j > 0$.

Hypothesis 2: Fine wines trigger an illiquidity premium.

If investors perceive the wine market as riskier because of its lack of liquidity, they should then ask for a reward for gaining exposure to this source of risk. As a consequence, γ_w from model [5] should be significantly positive. Likewise, if the wine market reacts with a delay to changes in market-wide liquidity risk, then according to model [6], $\gamma_{w,k}$ should be significantly positive for $k > 0$. This hypothesis can be tested by looking at the T-stat attached to γ_w in model [5] and $\gamma_{w,k}$ in model [6].

5. Results

5.1. Indices estimation and evolution

Table 6 presents the results of the estimation of equation [2]. We consider three different specifications based on the variables presented in Table 5. All specifications achieve high R^2, ranging from 0.77 for the first specification to 0.87 for the third one. Specifications 1a and 1b, which are the most parsimonious (because they do not include specific vintage dummies), illustrate that the relation between age and price is, on average, positive and convex. The impact of the ageing process is especially strong for outstanding vintages, which see their prices increasing at a steady rate of 2.6% per year. For such vintages, almost no quadratic relation exists between age and price. For vintages deemed less than outstanding, the linear relation is either close to zero (for very good vintages) or even negative (for good, average, and poor vintages). This difference can be justified by the fact that outstanding vintages reach their peak at a much older age than other vintages. Nevertheless, normal vintages also exhibit a significant convex relation between age and price, indicating that although the prices for such vintages tend to decrease during their first years on the market, they then tend to stabilize before eventually slightly rebounding. Our results are in line with those from Dimson et al. (2015) and support the concept that the ageing potential of a wine strongly depends on vintage quality. Specifications 2 and 3 allow investigating in greater detail the relation between vintage and price. The vintage coefficients estimated from these two specifications are nearly identical and are displayed in Figure 1. By far, the most expensive vintage is 1945, which is followed by other great vintages, such as 1947, 1949, 1959, and 1961. Apart from a few exceptions (such as 1982 and, to a lesser extent, 1989, 1990, and 2000), recent vintages tend to be much cheaper than the legendary years.

< Insert Table 6 here >

< Insert Figure 1 here >

The coefficients attached to each château are very stable from one specification to another, thereby supporting the robustness of our results. In general, wines from the same appellation trade at similar prices. Among the fourteen wines from our sample, Pavie and Angélus are the least expensive because they trade at a discount of more than 50% compared with Château Mouton-Rothschild (used as a reference in the regressions). This price difference is due to the fact that these two estates were only very recently upgraded to First Growth A status (in 2012). Mission Haut-Brion (approximately –30%) and Haut-Brion (–5%) also tend to be cheaper than Mouton-Rothschild. Yquem and Margaux trade at prices that are close to those of Mouton-Rothschild, while the wines from all other estates command higher prices. The two historical First Growth A wines from Saint-Emilion (Ausone and Cheval Blanc), and Latour from the commune of Pauillac, are on average 20% pricier than Mouton Rothschild. Lafite Rothschild, which is also from Pauillac, trades at a premium of more than 50% compared with Mouton Rothschild and is by far the most expensive wine from the Médoc and Graves regions. Finally, at the very high-end of the price spectrum are the two most exclusive wines from Pomerol—Pétrus and Le Pin—that cost approximately two to three times more than Mouton Rothschild.

< Insert Figure 2 here >

As previously discussed, Lafite Rothschild trades at a substantial premium compared with its neighbors. To investigate more precisely this "Lafite premium" and its evolution over time, we resort to specification 3. The corresponding coefficients are reported in Figure 2 and contrast with the evolution of a general wine index. We consider three wine indices on the basis of specifications 1 to 3.[26] Each of these indices aims to track the price evolution of all of the wines from our sample. A Wald test confirms that the Lafite coefficients are jointly significant (p-value of less than 0.01%) and thereby demonstrate that Lafite has followed a distinct path during the sample period. Figure 2 shows that the prices of Lafite Rothschild have remained close to those from the other First Growths during 2003–2007 and started to diverge in 2007. By 2008, the "Lafite premium" was close to 50%, then climbed to 100% in 2010 and, in 2011, finally reached higher than 150%. Since that time, the premium declined substantially and was slightly lower than 50% at the end of 2014.

Table 6 also demonstrates that quality is an important determinant of wine prices. The relation between Parker scores and wine prices is highly positive and convex, indicating that wines with scores close to 100 points sell for extremely high prices. The coefficients attached to the auction house and location dummies show that a wine sold by Acker Merrall & Condit or Sotheby's in Hong Kong is likely to achieve much higher prices than the same wine offered by Morrell or Edward Roberts International in the United States or in Europe. Since 2008 and the abolishment of taxes on wines, Hong Kong has emerged as a new hub for wine trading, which has led to a dramatic increase in interest and trading activity in this part of the world. This increased activity seems to have affected wine prices because the Hong Kong coefficient indicates that prices are on average 15% to 20% higher there than elsewhere in the world. Finally, a premium of 2% to 3% is attached to wines sold in their OWC. The quantity of a same wine offered at the same auction has a slightly negative impact on the hammer price. In general, each additional bottle leads to a decline in price of approximately 0.3% to 0.5%.

< Insert Figure 3 >

In Figure 3, we contrast the evolution of the wine index and two major stock market indices, the S&P 500 and the MSCI World. Wine prices have rapidly increased between 2005 and 2008 and then again between 2009 and 2011. These two periods of increase are associated with two combining factors: the advent of a great vintage (respectively, the 2005 vintage released "en primeur" in early 2006 and the 2009 vintage in 2010) combined with a bull stock market. In contrast, in 2008 and then again in 2011–2012, prices decreased substantially. The first correction, in 2008, parallels the financial crisis but was \ less severe than the decline in the stock markets. The second correction, in 2011, followed the bear market initiated by the Eurozone crisis and the release of the overpriced 2010 vintage.

[26] Auctions in August are not very common. For instance, in 2003 and 2004, no auction occurred in this month. To estimate the index level for those particular months, we have used an interpolation of the index level in the previous (July) and next (September) months. As a robustness test, we have run all of our analyses without those months and the results remain very similar.

< Insert Table 7 >

Table 7 contains descriptive statistics for key wine indices and compares them to the MSCI World and the S&P 500. During 2003–2014, an index consisting of all First Growths from all vintages achieved an average return of approximately 10% per year. As such, fine wines slightly outperformed stocks but were also much more volatile. Lafite Rothschild has generated higher returns than its siblings. The returns on all fine wine indices exhibit a positive skewness and a positive excess kurtosis. Returns on equity indices also display a positive excess kurtosis but are negatively skewed. This pattern suggests that fine wines often experience large positive returns, while stocks are more prone to experience large negative returns. Wine indices display a substantial degree of negative autocorrelation, suggesting that they tend to overreact and subsequently correct. The emotional nature of fine wines coupled with the fact that they do not deliver cash flow to their holders make them very prone to human biases, such as overreaction or speculative bubbles.[27]

5.2. Exposure of fine wines to market risk

Table 8 reports the results of the estimation of regression models [3] and [4]. We focus on the analysis of three wine indices. The first is estimated on the basis of specification 2 and can thus be regarded as a general index; the second and third indices are based on specification 3 and track respectively the evolution of all fine wines except Lafite Rothschild and Lafite Rothschild only. As such, a comparison of these two indices allows an examination of the specific behavior of Lafite Rothschild during the last decade. We use the MSCI World as a reference index in the CAPM regressions.[28] The upper panel uses data sampled on a monthly basis, and the lower panel uses quarterly data. When estimating model [4], we use a number of lagged market returns, which is sufficient to account for up to one complete quarter of a delay in the reaction of the wine market compared with stock markets. That is, for monthly data, we use up to three lagged market returns to calculate the total exposure of wine to market risk. For quarterly data, we use only one lag. This choice is supported by the Akaike and Schwarz information criteria, which both indicate that including more lags in the regressions is unnecessary.

< Insert Table 8 >

Our results demonstrate that the conventional beta is not only positive but also significant. When monthly data and only contemporaneous market returns are used, the beta turns out to be close to 0.30, which is considered fairly low. However, if the sampling frequency is lowered or lagged market returns are added to the CAPM regression, the R^2 of the regressions and the beta increase substantially. When quarterly data are used, the beta indeed reaches values of approximately 0.60 to 0.70. A bootstrap simulation further demonstrates that the difference between the beta obtained from quarterly and monthly data is statistically significant. This result provides support for hypothesis 1a. Note that even with monthly data, when lagged market returns are used, the *total* beta increases and consistently exceeds 0.50. In general, the beta at lag 1 is the largest and

[27] See Jovanovic (2013) for a detailed analysis of this phenomenon in the context of fine wine.
[28] We obtain similar results when using the S&P 500 instead of the MSCI World.

most significant. Adding another lag to the regression is not useful because the corresponding betas, although generally positive, are not significant. These results hold for the three wine indices considered so far. Thus, hypothesis 1b is validated.

Contrary to most recent studies on wine as an investment, *none* of the alphas turns out to be significantly positive because of three elements: our indices are more precise and more reactive than those used in the literature to date; we use a methodology that explicitly accounts for the potential consequences of illiquidity; and our sample period is longer and more recent (see section 5.5 for an analysis of the impact of considering different sample periods). Interestingly, the Lafite Rothschild index seems to be most sensitive to stock market returns because its total beta is typically between 0.70 and 0.80. This result is not surprising given the speculative frenzy that has surrounded this wine during 2009–2011 and the number of wine funds that have heavily invested in it.

5.3. Exposure of fine wines to liquidity risk

Table 9 is structured similar to table 8 and reports the results for models [5] and [6], thereby enabling an observation of whether hypothesis 2 holds. The betas are not affected by the inclusion of the liquidity risk factor into the regression and remain very stable compared with those obtained using models [3] and [4]. Table 9 further shows that the returns to fine wines are also strongly affected by their exposure to liquidity risk.

< Insert Table 9 >

For monthly data, the contemporaneous exposure of fine wines to liquidity risk, captured via γ in model [5], turns out to be distinctly larger than the exposure to market risk, measured by β. When lagged realizations of market and liquidity risks are added to the regression (model [6]), one observes that the wine market tends to react with a delay to changes in stock market conditions (because $\beta_{lag\ 1}$ is larger and more significant than the contemporaneous beta) but adapts more rapidly to changes in liquidity risk (because the contemporaneous γ is much larger and more significant than $\gamma_{lag\ 1}$). The results are slightly different when quarterly data are considered. In this case, both β and γ are highly significant, which again indicates that fine wines are affected by market and liquidity risk. Moreover, $\gamma_{lag\ 1}$ —albeit not always significant (p-values ranging between 7% and 14%)—is rather large, thereby indicating that changes in liquidity may affect returns to fine wines for up to two quarters. This result suggests that the liquidity conditions prevailing on the stock market may have a long-lasting effect on markets for less liquid assets, such as fine wines. Lafite Rothschild appears again to be the most "financialized" wine because it maintains the strongest exposure to both market and liquidity risk.

In summary, the results presented so far illustrate that the lack of liquidity in the wine market does not only impact its speed of adjustment to changes in financial conditions but is also perceived as a source of risk by investors who require compensation for being exposed to it. Thus, hypothesis 2 is validated. As a byproduct and in contradiction to most recent studies, our results indicate that fine wines do not benefit from a significantly positive alpha and that a substantial part of their returns can be explained by common risk factors.

5.4. Subsamples analysis

Hereafter, we examine the exposure of seven specific wine indices to market and liquidity risks. These indices are constructed on the basis of subsamples that contain only selected wines: the first index considers only the wines rated as perfect (100/100) by Robert Parker; the second and third indices contain wines from the left (Médoc and Graves) and the right (Saint-Emilion and Pomerol) bank of the Gironde; the fourth and the fifth indices focus respectively on old (i.e., from 1981 and earlier) and young wines (post-1981); and, finally, the remaining two indices are based on wines traded the least and the most often. The primary objective of this subsample analysis is to examine how the liquidity and the degree of financialization of particular wines affect their returns and exposure to risk factors. For instance, older wines tend to attract more amateurs and collectors, while younger wines are generally favored by investors. Thus, the inclusion into the analysis of two separate indices for young and old wines enables us to examine whether a clientele effect exists and affects the risk and return features of certain categories of fine wines. In addition, this subsample analysis enables us to determine whether particular types of wines offer better performance than others. Finally, this analysis allows testing of the stability of the results presented in the previous subsection. As such, this analysis can be considered a robustness test. The results are presented in table 10.

< Insert Table 10 >

The results for specific wine categories are generally in line with those obtained in the previous subsection. That is, all types of fine wines seem to be exposed to some degree of market and liquidity risks. Panel A (monthly data) indicates that wines from the right bank of the Gironde, old wines, and less often traded wines display a lower exposure to market risk than the other wines. These types of wines also maintain a relatively low R^2, which further demonstrates that they are less sensitive to financial conditions. This result is not a surprise given that those wines are less "financialized" than their counterparts. Indeed, investors and fund managers look for investing in wines that can easily be found on the market to reduce search and transaction costs. These wines are produced in relatively large quantities (such as on the left bank of the Gironde), that come from young vintages (still available from most wine merchants), and that are logically the most liquid.

For data sampled on a quarterly basis (panel B), β turns out to be clearly positive and highly significant, while γ is found to be positive but not always significant. As before, $\lambda_{lag\ 1}$ is often large and significant and seems to be especially large for those "myths" that have been deemed a perfect score from Robert Parker and wines from the right bank, from older vintages, and that are less actively traded. These wines are a bit more difficult to find on the market and tend to attract, first and foremost, the interest of collectors as opposed to genuine investors. Collectors are likely to face similar constraints as investors but perhaps with some delay, which may explain this result. In general, the difference in risk exposure among the various categories of wines is less pronounced when quarterly data are used, suggesting that over long horizons, all wines end up being affected by financial and economic conditions. Overall, note that *all* wine categories are sensitive to market and liquidity risks and none of the wine indices generate a significantly positive alpha.

5.5. Robustness tests

As discussed in the literature review, assessing the performance of an investment in wine crucially depends on the research design on which one settles. In particular, the results might be affected by the category of wines considered (see section 5.4 for a detailed analysis); the type of prices used in the analysis; the period under investigation; the methodology used to construct a portfolio or index; the asset pricing models; and the benchmark indices used to assess performance. To ensure that our results are reliable and not driven by specific choices regarding the research design and the methodology used, we conduct various robustness tests.[29]

1. **Type of prices used:** Our indices are constructed using only auction price data. Hammer prices present a key advantage over retail prices because they correspond to effective transaction prices. However, they only represent a relatively small part of all transactions on the market for fine wines. Therefore, to ensure that the auction prices used in this study reflect the overall evolution of the wine market, we recalculate all statistics using the Liv-ex 100 index, which is similar in its construction to our base index because it gives a strong weight to wines from Bordeaux. The Liv-ex 100 index is constructed using prices recorded on the Liv-ex proprietary trading platform.
   Comments: The construction of the Liv-ex 100 index makes it smoother and less reactive than our indices. As such, it typically maintains a lower volatility and displays a positive autocorrelation. Nevertheless, its exposure to market sources is quite comparable to those obtained using our indices, especially when low-frequency data are used.

2. **Period under supervision:** To ensure that our results are robust and not driven by specific events (such as, for instance, the emergence of Hong Kong as a major auction place since 2008), we divide the sample period into two sub-periods of equal length and recalculate all statistics. The first sub-period runs from 2003 to 2008, and the second sub-period covers the second half of our sample and ends in 2014. Interestingly, the first sub-period corresponds to a time of prosperity with moderate inflation, while the second corresponds to a period of economic stagnation with no inflation. In a second step, we further investigate how fine wines react during periods of market stress (such as the global financial crisis of 2007–2009, or the Eurozone crisis in 2011). To do so, we look at the performance and risk features of an investment in fine wines during periods when the volatility[30] averages 20% or more.
   Comments: The results indicate that the returns were clearly larger during the first period (2003–2008) than the second (2009–2014). When focusing on the results obtained by applying the conventional beta, the contemporaneous beta and the beta at lag 1 appear to have been quite similar during both periods. Both the beta at lag 2 and the alpha were much larger in period 1 compared with period 2. However, when both market and liquidity risks are taken into account, the results become quite different and the alpha declines to almost zero for period 1 as well. This finding indicates that liquidity risk has had a stronger impact on wine returns during the first period. This observation may help reconcile our results with those from previous studies. Indeed, most studies find a positive alpha and a beta that is very close to zero.
   Furthermore, during periods of high volatility, we observe that the exposure of fine wine to market risk tends to decline and that its exposure to liquidity risk increases. Unfortunately,

[29] Detailed results are not reported in this study but are available from authors on request.
[30] We use the S&P 500 implied volatility index, the VIX (aka the "fear index"), to track the volatility of financial markets.

the number of observations during such high volatility environments remains limited and, consequently, the results are not significant. Nevertheless, this observation may explain part of the results from Masset and Weisskopf (2010), who show that the conditional beta of wine tends to be low even during periods of financial instability and that its conditional alpha declines during such periods. The result previously discussed suggests that this decline in the alpha could be explained by an increase in liquidity risk and, thus, could be interpreted as the manifestation of a flight to liquidity phenomenon.

3. **Index construction methodology:** We re-estimate all of our wine indices using the RSR approach instead of the HR approach. The RSR is constructed in way that mechanically controls for all sources of heterogeneity among different wines but uses only wines that have been traded at least twice. As such, the resulting wine index may have (slightly) different statistical properties from the one obtained using the HR approach.
   Comments: Again, the results do not change significantly when indices computed using the RSR approach are used.

4. **Benchmark indices:** Given the complex and international nature of the wine market, in addition to the MSCI World and S&P 500 indices, we re-estimate the beta using several other benchmark indices. In particular, we consider the CAC 40 (because Bordeaux First Growths are produced in France, it seems logical to use a French stock market index), the FTSE 100 (most wine investment companies and funds are based in London), and the Hang Seng Index (during the last decade, Hong Kong has rapidly emerged as one of the most important marketplaces for Bordeaux wines).
   Comments: Whichever reference stock market index is considered, fine wines maintain a positive exposure to market risk. In general, however, the beta is lower when the CAC 40 or the FTSE 100 is used instead of the MSCI World, the S&P 500, or the HSE.

5. **Asset pricing model and risk factors:** So far, we have considered only two sources of systematic risk, namely market and liquidity risk. However, other risk factors may affect wine returns. Therefore, we complement our analysis by using three additional factors: the SMB and the HML factors of Fama and French (1992, 1993) and the MOM of Carhart (1997). These factors have already been found to explain a substantial part of stock returns. Fine wines, such as other collectibles, are often considered alternative assets. As such, their price dynamics and returns are likely to be affected by risk factors that differ from those affecting stock and bond prices. Therefore, we run an additional robustness test using five risk factors that have been found to explain a substantial part of the returns to alternative investments (see, e.g., Fung and Hsieh (2001, 2002, and 2004)).
   Comments: Apart from the conventional beta, none of the additional factors turns out to be consistently significant in the regressions. This finding suggests that these additional factors are not relevant in explaining the returns to an investment in fine wine. One reason may be due to the fact that the SMB, HML, and MOM factors have been designed to be applied on stocks, while the purpose of the Fung and Hsieh factors is first and foremost to replicate various types of hedge fund investment strategies. This result further reinforces the conjecture that liquidity risk is likely to affect many asset classes and not just the most liquid ones (such as stocks and bonds).

6. Conclusion

In this paper, we estimate several indices that track the performance of various categories of fine wines during 2003–2014. All of these indices have achieved important returns, often close to or even larger than 10% per year. From this perspective, fine wines have fared better than most other asset classes during this period. However, note that fine wines have also been quite volatile and have experienced a substantial price correction since 2011. Moreover, fine wines appear to be significantly exposed to market and liquidity risks. Fine wines tend to react with a delay of approximately one to three months to changes in market conditions. This delay can be explained by the lack of liquidity in the wine market that impedes more rapid adjustments. Liquidity risk also seems to have a substantial effect on wine returns. Put together, these results indicate that when one properly accounts for the relative illiquidity of the wine market and its effects on price dynamics (delayed reaction) and investors' risk perception (liquidity risk), wine investments turn out to be riskier than usually thought. Even worse, such investments do not appear to generate significant abnormal returns. The relatively high R^2 (compared with previous studies) obtained in most test specifications and a variety of robustness tests further strengthen the evidence presented in this paper.

From an academic viewpoint, the observation that a substantial part of the returns stemming from wine investments can be explained by their exposure to common risk factors and, in particular, to liquidity risk stands in clear contradiction to previous evidence (see, e.g., Sanning et al. (2008) and Masset and Weisskopf (2010)) on the performance of such investments. Nevertheless, this observation is in perfect agreement with the literature on alternative investments. Assets such as private equity, real estate, and hedge funds tend to be rather illiquid and can become especially difficult to sell when markets tumble. Thus, investors generally need to be compensated for bearing this type of risk. Furthermore, the fact that a liquidity factor estimated on the basis of stock returns can explain the returns on an exotic asset such as wine suggests that illiquidity is a common, cross-asset source of risk. Hence, this paper does not only contribute to the literature on alternative investments and wine as an asset class but also provides additional evidence regarding the nature of liquidity risk.

From a practical viewpoint, the results presented in this paper are certainly disappointing for wine investors but do not invalidate such investments. They simply demonstrate that fine wines and, more particularly, simple buy-and-hold strategies involving fine wines do not deliver positive abnormal returns. This finding suggests that such investments are riskier than usually thought and require a genuine understanding of the wine market. Nevertheless, wine investments can still be interesting in terms of diversification and, more importantly, may allow investors to obtain important exposure to particular sources of risk, such as liquidity risk. Notably, such an exposure can be particularly relevant for investors with a long-term investment horizon. Moreover, we show that different types of wines can display rather dissimilar price dynamics. For instance, investing in old vintages may enable better diversification because those wines have a lower correlation with other asset categories. All in one, our results suggest that it is naïve to expect abnormal returns just by investing "blindly" in a static basket of First Growths from the most recent and adulated vintages. To develop a successful investment strategy, a thorough analysis is crucial to identifying genuine opportunities. This observation opens the door for dynamic and creative investment strategies with dedicated risk exposure.

7. List of references

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Table 1: Overview of the existing literature

Authors (year) *Source*	Data	Methodology used	Period	Performance		
				Returns	Volatility	Diversification
KRASKER (1979) *Journal of Political Economy*	Annual Heublein Wine Auction. 137 observations (red Bordeaux and California Cabernet Sauvignon; vintages before 1950 are excluded).	PR: dep = excess returns to wine; indep = constant + storage costs. The constant provides an estimate of the difference in return between wine and US T-	1973 - 1977	Wines do not outperform US T-bills in terms of returns.	*Not investigated*	*Not investigated*
JAEGER (1981) *Journal of Political Economy*	Annual Heublein Wine Auction. 199 observations (red Bordeaux and California Cabernet Sauvignon; vintages before 1950 are excluded).	Same approach as Krasker (1979), except that the storage costs are not estimated (explicitly set to USD 0.449 per bottle and per year).	1969 - 1977	Wines do significantly outperform US T-bills in terms of returns.	*Not investigated*	*Not investigated*
BYRON and ASHENFELTER (1995) *Economic Record*	Langton's auctions. Penfold's Grange, vintages 1959 to 1987.	HR: indep = age + weather variables. The coefficient associated to the age variable provides an estimate of the expected real rate of return to holding wine. TS: dep = return; indep = constant.	1991 - 1994	3.9% real rate of return (HR) (12-13% in nominal terms). 18% nominal rate of return (TS).	*Not investigated*	*Not investigated*
De VITTORIO and GINSBURGH (1996) *Journal de la Société Statistique de Paris*	Christie's wine auctions (London). 29,901 observations (red Bordeaux; vintages 1949-1988).	HR: indep = year of sale + age + other variables.	1980 - 1992	3.7% (expected real rate of return - ageing effect). 4.2% (average nominal rate of return over the period).	10.20%	*Not investigated*
BURTON and JACOBSEN (2001) *Economic Inquiry*	Edgerton (1986-1997) *Wine Price File.* 10,558 observations (red Bordeaux; vintage after 1960; bi-annual data).	RSR: estimation of several wine indices. Analysis of the returns of the various wine indices.	1986 - 1996	Average return of 7.9% for a diversified wine portfolio (13.9% for 1982 Wines offer higher returns than bonds but lower than equities.	18.8% (diversified portfolio; 19% for 1982 Bordeaux). Wines are much more volatile than stocks and bonds.	*Not investigated*
JONES and STORCHMANN (2001) *Agricultural Economics*	Blättel and Stainless (auction data) 306 observations (21 Bordeaux wines; vintages 1980-1994).	PR (close in spirit to a HR): dep = price; indep = age + Parker points + other variables. Primary purpose is to forecast wine prices.	1996	Annual real rate of return of 1.2% to 9.6% (depending on the château).	*Not investigated*	*Not investigated*
FOGARTY (2006) *European Review of Agricultural Economics*	Langton's auctions. 14,102 observations (84 Australian wines; vintage before 1965 are excluded).	HR: indep = period of sale + quality-related variables.	1989 - 2000	Quarterly rate of return: 2.35%. Subindices defined on the basis of price offer different returns (3.17% for the most expensive, 1.92% for the cheapest). Australian Equities: 2.67%.	Quarterly volatility: 4.42% (respectively 4.74% and 5.34% for the most and the least expensive wines). Australian Equities: 2.18%.	*Not investigated*
SANINNG et al. (2008) *Journal of Wine Economics*	The Chicago Wine Company (auction data). 13,662 observations (90 red wines; vintage 1893-1998).	Wine returns calculated from repeated transactions and for each wine separately. Performance analysed using the CAPM and the Fama-French Three Factor model.	1996 - 2003	Average excess return of 7.5% to 9.5% p.a. Abnormal returns (alpha) on average positive and significant.	Depending on the category of wine considered, the volatility varies between 21% and 27%.	Beta insignificant and close to 0 (and often slightly negative). Wine offers an important diversification potential.

Table 1 (con't)

Authors (year) *Source*	Data	Methodology used	Period	Performance Returns	Volatility	Diversification
FOGARTY (2010) *Journal of Wine Economics*	Langton's auctions. 12,180 observations (84 Australian wines).	RSR: estimation of a wine index for Australian wines. Tests to determine if adding wine to a portfolio improves its risk-return profile.	1990 - 2000	Average quarterly return of 2.05% versus 2.67% for Australian equities and 2.84% for Australian bonds.	Wines have a lower volatility (3.93%, quarterly basis) than Australian equities (5.80%) but higher than bonds (3.15%).	Wines are weakly correlated with equities (correlation of 0.14) and negatively with bonds (-0.11). They provide diversification
MASSET and HENDERSON (2010) *Journal of Wine Economics*	The Chicago Wine Company (auction data). 77,014 observations (92 red Bordeaux; from 29 vintages).	Wine indices calculated from repeated transactions. Mean-variance and higher-moment portfolio analyses	1996 - 2007	Total cumulated return of the wine market index of 145% (220% for outstanding wines) versus 127% for the Dow Jones.	The general wine market index has a lower volatility than the Dow Jones (8.1% versus 15%).	Limited correlation between wines and other assets. Wine improves a portfolio's risk-return profile.
KOURTIS et al. (2012) *International Review of Financial Analysis*	WinePrice (2005 to 2010) and Liv-ex. Monthly indices (wines from several countries).	Analysis of the diversification potential offered by wines from different countries. Proposition regarding the development of dedicated wine derivatives.	2001 - 2010	High returns, though dependent on the region considered. Average monthly return of 2% (Australian wines) to 18% (Bordeaux).	Volatility of 18% (Californian wines) to 28% (Bordeaux). Volatility generally higher than for equities.	Limited correlation of wine with equities (<0.3). Diversification potential offered by wines from different origins.
DIMSON et al. (2015) *Journal of Financial Economics (Forthcoming)*	Christie's London (auction data) and Berry Bros. & Rudd (retail prices) 36,271 observations (First growths from Bordeaux).	Value-weighted RSR to estimate a wine index. Analysis of the returns to wine investments (using a market models) and of their life-cycle price dynamics (within a HR framework).	1899 - 2012	Average real rate of return of 5.3% (4.1% after adjustments for insurance and storage costs) versus 5.2% for equities, 1.5% for bonds, 2.4% for art and 2.8% for stamps.	Wines are much more volatile than other asset classes (volatility of 26.9% on annual basis) including equities (21.6%), bonds (11.9%), art (13.2%) and stamps (13.5%).	Wines are significantly correlated with equities. Their total beta is between 0.57 and 0.73 (depending on the period considered).
DEVINE and LUCEY (2015) *Research in International Business and Finance*	The Chicago Wine Company (auction data) and data on wine funds. 69,903 observations (Bordeaux and Rhone wines) and returns on 5 funds.	Index calculations using the RSR approach. Analysis of performance, primarily on the basis of the Sharpe ratio.	1996 - 2007	Average return of 5.2% for a diversified wine portfolio (3.2% for Bordeaux and 5.5% for Rhone), versus 4.9% for the Dow Jones.	Volatility of 9.1% for a diversified wine portfolio (10.4% for Bordeaux and 8.9% for Rhone), versus 17.6% for the Dow Jones.	*Not investigated*
MASSET and WEISSKOPF (2015) *Handbook of Wine Economics*	The Chicago Wine Company (auction data). More than 400,000 observations.	Index calculations using the RSR approach. Performance analyzed using the CAPM and the conditional CAPM.	1996 - 2009	Total return of 149% for a diversified wine index (63% for US wines; 198% for Bordeaux and 296% for Rhone) versus 42% for equities. Significant abnormal	Volatility of less than 15% for all wine indices and of just 8.2% for a diversified wine index; versus 17.9% for equities.	Low correlation between wine and equities. Beta is close to 0 or even slightly negative.
MASSET and WEISSKOPF (2015) *Journal of Alternative Investments*	Monthly closing values of 9 wine funds. Depending on the fund considered, 54 to 129 observations are available.	Analysis of fund managers' performance (including selectivity and market timing skills). Use of the CAPM, Fama-French three factors and Carhart four factors models.	2000 - 2013	Most funds beat the S&P 500 but not the S&P 500 Beverages and the bond indices. Abnormal returns are not significantly different from 0 for all funds but one.	All but two funds have a lower volatility than equity indices. They are however more volatile than the bond index.	Most funds have a positive and significant beta.

Notes: CS: cross-sectional regression; TS: time-series regression; PR: panel regression; HR: hedonic regression; RSR: repeat-sales regression; dep: dependent variable; indep: independent variable(s). For the HR approach, the dependent variable is always the log-price, while it is the return in the case of the RSR approach.

Table 2: Average price and trading activity per Château and per year

Panel A	Average price													
	Médoc and Graves						St-Emilion				Pomerol			Sauternes
	Haut-Brion	Lafite Rothschild	Latour	Margaux	Mouton Rothschild	Mission Haut-Brion	Angélus	Ausone	Cheval Blanc	Pavie	Lafleur	Pétrus	Le Pin	Yquem
2003	287.27	264.48	424.04	272.32	312.47	353.78	98.67	174.69	386.92	93.64	649.55	938.38	968.00	479.79
2004	334.22	303.84	396.31	307.04	378.06	351.18	113.31	233.46	489.74	129.35	580.59	1 064.72	911.51	603.13
2005	403.31	361.65	537.51	355.06	385.18	453.28	129.36	257.34	575.56	129.50	897.83	1 283.79	1 142.29	660.48
2006	506.08	475.10	629.41	417.44	559.18	559.30	169.83	338.28	626.90	152.03	1 494.25	1 622.48	1 736.01	645.24
2007	612.77	796.39	768.31	612.94	663.16	684.60	168.02	641.46	924.95	209.18	1 139.51	1 994.43	2 061.63	983.62
2008	538.51	871.65	725.92	574.50	571.16	610.29	179.86	754.64	725.91	184.10	1 044.87	1 880.67	1 638.99	657.28
2009	542.23	914.03	672.10	499.07	597.83	577.22	179.91	831.96	678.96	196.57	869.04	1 731.07	1 683.08	609.59
2010	650.24	1 632.77	908.01	707.31	818.51	612.38	236.69	1 018.46	850.17	235.61	1 026.16	2 336.30	2 080.22	556.72
2011	709.10	1 593.15	1 021.06	712.13	826.49	694.23	263.79	927.61	757.84	253.80	1 070.79	2 514.10	2 161.05	598.65
2012	600.37	1 120.82	870.11	569.20	782.38	652.90	280.77	622.96	802.26	280.22	1 039.94	2 200.43	2 209.81	626.08
2013	685.37	1 078.80	866.76	592.26	766.05	590.58	297.78	673.41	790.64	296.43	1 038.40	2 555.49	2 302.51	492.94
2014	622.24	920.44	789.21	560.68	765.33	554.05	303.30	655.66	643.31	289.20	1 044.83	2 457.37	2 549.48	546.78

Panel B	Number of trades per auction month and average trade size													
	Haut-Brion	Lafite Rothschild	Latour	Margaux	Mouton Rothschild	Mission Haut-Brion	Angélus	Ausone	Cheval Blanc	Pavie	Lafleur	Pétrus	Le Pin	Yquem
2003	70 (11)	83 (13)	88 (11)	78 (12)	101 (14)	37 (11)	18 (14)	11 (10)	47 (11)	10 (14)	16 (7)	66 (7)	9 (8)	39 (7)
2004	94 (10)	120 (10)	113 (9)	100 (10)	145 (10)	48 (9)	19 (11)	11 (9)	56 (9)	13 (11)	20 (7)	77 (6)	9 (7)	44 (6)
2005	90 (9)	122 (9)	115 (8)	102 (9)	180 (10)	44 (9)	21 (11)	16 (9)	72 (9)	17 (11)	18 (6)	83 (6)	8 (7)	51 (6)
2006	88 (9)	122 (9)	117 (8)	122 (10)	153 (9)	47 (9)	17 (10)	17 (8)	78 (8)	20 (11)	26 (7)	96 (6)	13 (5)	58 (6)
2007	114 (9)	157 (9)	134 (9)	129 (9)	183 (9)	58 (9)	26 (11)	19 (8)	80 (8)	16 (10)	28 (8)	106 (6)	11 (4)	52 (5)
2008	142 (10)	207 (10)	162 (10)	152 (9)	201 (10)	54 (9)	27 (11)	23 (8)	79 (9)	25 (11)	31 (7)	108 (6)	18 (7)	60 (7)
2009	107 (10)	143 (10)	110 (9)	116 (10)	141 (10)	52 (11)	17 (11)	19 (8)	77 (9)	23 (11)	23 (8)	79 (7)	12 (7)	41 (7)
2010	154 (10)	296 (9)	189 (10)	180 (10)	243 (10)	77 (10)	35 (11)	38 (9)	104 (9)	43 (11)	32 (8)	115 (7)	17 (6)	59 (7)
2011	186 (9)	451 (8)	241 (9)	222 (9)	307 (10)	77 (9)	39 (11)	40 (9)	120 (10)	34 (11)	28 (8)	134 (6)	16 (6)	63 (7)
2012	144 (10)	245 (9)	170 (9)	162 (10)	217 (9)	76 (10)	30 (10)	27 (9)	114 (9)	36 (11)	24 (8)	108 (6)	16 (5)	55 (8)
2013	107 (10)	159 (9)	111 (9)	119 (10)	144 (9)	55 (10)	20 (11)	20 (8)	65 (9)	28 (11)	21 (8)	79 (6)	14 (5)	57 (9)
2014	101 (10)	149 (9)	110 (9)	101 (10)	159 (9)	48 (10)	16 (10)	19 (9)	65 (10)	24 (11)	15 (7)	78 (6)	13 (5)	50 (8)

Note: The average trade size is defined as the average number of bottles per lot; this information is reported in brackets next to the number of trades per month.

Table 3: Average price and percentage of trades per vintage (as of 2014)

	Average price	Trading activity		Average price	Trading activity		Average price	Trading activity
1945	5 361	7 (2)	**1967**	925	5 (6)	**1989**	1 083	41 (9)
1946	2 069	1 (1)	**1968**	1 064	1 (4)	**1990**	936	52 (9)
1947	3 735	3 (2)	**1969**	580	1 (6)	**1991**	465	3 (9)
1948	1 485	2 (2)	**1970**	725	14 (8)	**1992**	534	4 (9)
1949	2 251	4 (2)	**1971**	919	4 (7)	**1993**	486	10 (9)
1950	1 288	2 (4)	**1972**	350	2 (10)	**1994**	641	11 (9)
1951	373	1 (2)	**1973**	553	2 (6)	**1995**	590	45 (10)
1952	1 006	2 (3)	**1974**	753	3 (8)	**1996**	660	49 (10)
1953	895	3 (3)	**1975**	779	13 (7)	**1997**	469	16 (10)
1954	711	1 (3)	**1976**	577	7 (7)	**1998**	689	39 (10)
1955	1 236	4 (4)	**1977**	426	2 (7)	**1999**	535	29 (10)
1956	639	1 (1)	**1978**	538	10 (9)	**2000**	1 198	66 (9)
1957	538	1 (5)	**1979**	641	7 (8)	**2001**	606	33 (10)
1958	469	1 (3)	**1980**	398	2 (8)	**2002**	541	25 (10)
1959	1 835	10 (4)	**1981**	504	7 (9)	**2003**	595	51 (10)
1960	695	1 (3)	**1982**	1 598	68 (7)	**2004**	555	30 (10)
1961	2 387	10 (4)	**1983**	538	16 (9)	**2005**	768	39 (10)
1962	931	3 (4)	**1984**	615	3 (8)	**2006**	546	23 (10)
1963	718	1 (7)	**1985**	573	17 (9)	**2007**	568	12 (9)
1964	735	6 (6)	**1986**	765	42 (9)	**2008**	570	31 (11)
1965	498	1 (3)	**1987**	439	4 (8)	**2009**	863	24 (11)
1966	667	7 (6)	**1988**	661	25 (9)	**2010**	1 232	11 (9)

Note: The column "trading activity" shows the number of trades per auction month and, in brackets, the average trade size (defined as the average number of bottles per lot).

Table 4: Turnover at the various auction houses and locations (in USD and in percentages)

	Asia		North America		Europe		Total	
Acker Merrall & Condit	89 243 704	9.3%	64 140 195	6.7%	-	0.0%	153 383 899	16.0%
Bonhams	6 266 472	0.7%	12 994 369	1.4%	12 334 649	1.3%	31 595 489	3.3%
Christie's	69 789 915	7.3%	64 651 766	6.7%	106 845 474	11.1%	241 287 154	25.1%
Hart Davis Hart Wine	-	0.0%	94 867 710	9.9%	-	0.0%	94 867 710	9.9%
Morrell and Company	-	0.0%	14 540 621	1.5%	-	0.0%	14 540 621	1.5%
Sotheby's	90 029 817	9.4%	64 464 193	6.7%	99 086 305	10.3%	253 580 316	26.4%
Edward Roberts	10 532 614	1.1%	8 201 732	0.9%	271 642	0.0%	19 005 988	2.0%
Zachy's	63 802 386	6.6%	89 485 706	9.3%	-	0.0%	153 288 092	15.9%
All auction houses	329 664 908	34.3%	413 346 292	43.0%	218 538 070	22.7%	961 549 269	100.0%

Table 5: list of variables used in the hedonic regression

Variables	Details	Used in specification			
		1a	1b	2	3
A. Variables specific to the wine auctioned :					
Château	Dummy variables for Latour, Lafite Rothschild, Mouton Rothschild, Margaux, Haut-Brion(*)	×	×	×	×
Lafite premium	Interaction term between the Lafite and time dummies (used to estimate a time-varying premium)				×
Vintage	Dummy variables for vintages 1945 to 2009			×	×
Age	Age of the wine	×			
Age^2	Squared age of the wine	×			
Age × Vintage quality	Interaction term between age and a set of vintage quality dummy variables		×		
Age^2 × Vintage quality	Interaction term between age^2 and a set of vintage quality dummy variables		×		
Rating availability	Dummy variable that takes value 1 if the Parker's rating is available for a particular wine and 0 otherwise				
Rating	Parker's rating	×	×	×	×
$Rating^2$	Squared Parker's rating	×	×	×	×
B. Variables specific to to a particular transaction :					
Time of sale	Dummy variables for January 2003 to December 2014 (used to construct the index)	×	×	×	×
Auction house	Dummy variables for Acker Merrall & Condit, Bonhams, Christie's, Hart Davis, Morrell, Sotheby's, Spectrum and Zachy's	×	×	×	×
Auction location	Dummy variables for Asia, North America and Europe	×	×	×	×
OWC-6	Dummy variable to control if the wine is sold in the 6-bottle Original Wooden Case (OWC)	×	×	×	×
OWC-12	Same as OWC-6 but for 12-bottle OWC.	×	×	×	×
Quantity	Number of bottles sold in a particular lot	×	×	×	×

Note 1: we consider three particular hedonic regression specifications; the variables used in each specification are indicated in the column denoted as "used in specification 1 to 3".

Note 2: in specification "1b", a set of vintage quality dummy variables (five dummy variables, for poor to great vintages) is used to model the joint effect of age and vintage's quality on prices.

(*) : the Lafite dummy is not used in specification 3 (it would be multicolinear with the Lafite premium

Table 6: Coefficient estimates from the hedonic regression

	Specification 1a		Specification 1b		Specification 2		Specification 3	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Intercept	4.8280	<0.01%	4.8609	<0.01%	6.6802	<0.01%	6.7662	<0.01%
Angélus	-0.7290	<0.01%	-0.7660	<0.01%	-0.7734	<0.01%	-0.7758	<0.01%
Ausone	0.2298	<0.01%	0.1820	<0.01%	0.1705	<0.01%	0.1773	<0.01%
Cheval Blanc	0.2643	<0.01%	0.1896	<0.01%	0.1795	<0.01%	0.1781	<0.01%
Haut-Brion	-0.0530	<0.01%	-0.0437	<0.01%	-0.0631	<0.01%	-0.0624	<0.01%
Lafite Rothschild	0.4003	<0.01%	0.4314	<0.01%	0.4445	<0.01%		
Lafleur	0.4410	<0.01%	0.4669	<0.01%	0.4680	<0.01%	0.4650	<0.01%
Latour	0.1599	<0.01%	0.1624	<0.01%	0.1828	<0.01%	0.1845	<0.01%
Margaux	-0.0217	<0.01%	-0.0032	40.50%	0.0081	2.17%	0.0088	0.80%
Mission Haut-Brion	-0.3476	<0.01%	-0.3223	<0.01%	-0.3455	<0.01%	-0.3460	<0.01%
Pavie	-0.7653	<0.01%	-0.8259	<0.01%	-0.8613	<0.01%	-0.8575	<0.01%
Pétrus	1.2107	<0.01%	1.2807	<0.01%	1.3192	<0.01%	1.3205	<0.01%
Le Pin	1.4163	<0.01%	1.4312	<0.01%	1.4274	<0.01%	1.4314	<0.01%
Yquem	-0.1374	<0.01%	-0.0319	<0.01%	-0.0125	1.39%	-0.0178	0.02%
Age	0.0048	<0.01%						
Age^2	0.0003	<0.01%						
Age × Poor vintage			-0.0128	<0.01%				
Age × Average vintage			-0.0195	<0.01%				
Age × Good vintage			-0.0073	<0.01%				
Age × Very good vintage			0.0003	48.54%				
Age × Outstanding vintage			0.0261	<0.01%				
Age^2 × Poor vintage			0.0006	<0.01%				
Age^2 × Average vintage			0.0007	<0.01%				
Age^2 × Good vintage			0.0004	<0.01%				
Age^2 × Very good vintage			0.0002	<0.01%				
Age^2 × Outstanding vintage			-0.0000	12.10%				
Rating availability	0.0912	<0.01%	0.1388	<0.01%	0.1848	<0.01%	0.1633	<0.01%
Rating	0.7584	<0.01%	0.5830	<0.01%	0.5359	<0.01%	0.5340	<0.01%
$Rating^2$	0.1575	<0.01%	0.1182	<0.01%	0.1140	<0.01%	0.1138	<0.01%
Bonhams	-0.1304	<0.01%	-0.1262	<0.01%	-0.1206	<0.01%	-0.1221	<0.01%
Christie's	-0.0105	1.43%	-0.0198	<0.01%	-0.0217	<0.01%	-0.0267	<0.01%
Hart Davis Hart	-0.0243	<0.01%	-0.0274	<0.01%	-0.0255	<0.01%	-0.0365	<0.01%
Morrell	-0.2092	<0.01%	-0.2120	<0.01%	-0.1951	<0.01%	-0.1883	<0.01%
Sotheby's	0.0339	<0.01%	0.0176	<0.01%	0.0145	<0.01%	0.0100	0.22%
Spectrum	-0.1366	<0.01%	-0.1306	<0.01%	-0.1239	<0.01%	-0.1191	<0.01%
Zachy's	-0.0462	<0.01%	-0.0497	<0.01%	-0.0518	<0.01%	-0.0562	<0.01%
Hong-Kong	0.1797	<0.01%	0.1681	<0.01%	0.1619	<0.01%	0.1561	<0.01%
Europe	-0.0560	<0.01%	-0.0365	<0.01%	-0.0279	<0.01%	-0.0282	<0.01%
OWC-6	0.0088	2.87%	0.0172	<0.01%	0.0201	<0.01%	0.0300	<0.01%
OWC-12	-0.0108	0.18%	0.0076	1.42%	0.0203	<0.01%	0.0313	<0.01%
Quantity	-0.0062	<0.01%	-0.0049	<0.01%	-0.0038	<0.01%	-0.0034	<0.01%
Observations :	152484		152484		152484		152484	
R^2 :	0.77	<0.01%	0.82	<0.01%	0.85	<0.01%	0.87	<0.01%

Note: the reference (intercept) is Château Mouton-Rothschild 1945 (for specifications 2 and 3) sold in the USA by Acker Merrall & Condit in January 2003.

Table 7: Descriptive statistics

	General hedonic indices						Stock market indices	
	Specification 1		Specification 2	Specification 3			MSCI World	S&P 500
	1a	1b		Index (without Lafite)	Lafite premium	Lafite index		
Average	9.3%	9.7%	10.4%	10.1%	4.6%	15.0%	8.1%	8.7%
Volatility	30.8%	29.6%	27.5%	27.6%	39.8%	31.9%	16.2%	15.1%
Skewness	0.80	0.71	0.56	0.58	1.14	0.94	-0.85	-1.02
Kurtosis	4.92	4.42	3.96	4.28	8.09	4.67	5.88	5.99
Autocorrelation	-0.19	-0.19	-0.20	-0.17	-0.29	-0.25	0.15	0.11

This table contains for each index: its average return, volatility, skewness and kurtosis.
Descriptive statistics for the Lafite premium are calculated on the basis of the premium of Lafite prices as compared to the other wines (instead of the returns).

Table 8: Results of the CAPM regressions (hypotheses 1a and 1b)

Panel A: Monthly data	**Specification 2**				**Specification 3**							
					Index (without Lafite)				**Lafite index**			
α	8.1%	6.0%	5.2%	5.4%	8.0%	5.8%	5.2%	5.3%	11.5%	8.8%	8.4%	8.3%
β	0.28*	0.23	0.23	0.24*	0.25*	0.20	0.20	0.20	0.41**	0.35**	0.35**	0.35**
$\beta_{lag\ 1}$		0.32**	0.3**	0.3**		0.33**	0.31**	0.31**		0.41**	0.4**	0.4**
$\beta_{lag\ 2}$			0.12	0.13			0.10	0.10			0.07	0.07
$\beta_{lag\ 3}$				-0.04				-0.02				0.02
Total β	0.28	0.55	0.66	0.63	0.25	0.52	0.61	0.59	0.41	0.76	0.82	0.84
Nobs.	143	143	143	143	143	143	143	143	143	143	143	143
R^2	0.03	0.06	0.07	0.07	0.02	0.06	0.06	0.06	0.04	0.09	0.09	0.09

Panel B: Quarterly data	**Specification 2**		**Specification 3**			
			Index (without Lafite)		**Lafite index**	
α	4.4%	4.7%	4.2%	4.4%	8.5%	7.9%
β	0.6***	0.61***	0.56***	0.56***	0.73***	0.71***
Delta β Q-M	*0.33**		*0.31**		*0.31**	
$\beta_{lag\ 1}$		-0.04		-0.03		0.08
Total β	0.60	0.57	0.56	0.54	0.73	0.79
Nobs.	47	47	47	47	47	47
R^2	0.30	0.30	0.27	0.27	0.28	0.28

Notes: results for models 3 and 4 are reported. Panel A shows the results for monthly data (Hypothesis 1a) and Panel B is for quarterly data (hypothesis 1b). Delta β corresponds to the difference between the monthly and quarterly estimates of the contemporaneous beta (β in model 3). *, ** and *** indicate significativity at the 10%, 5% and 1%-level. The alpha (α) is annualized.

Table 9: Results of the liquidity-augmented CAPM regressions (hypothesis 2)

Panel A: Monthly data	**Specification 2**				**Specification 3**							
					Index (without Lafite)				**Lafite index**			
α	5.6%	3.7%	2.0%	0.8%	5.5%	3.8%	2.1%	0.4%	8.0%	5.0%	4.4%	3.5%
β	0.28**	0.24*	0.19	0.16	0.25*	0.20	0.15	0.11	0.41**	0.38**	0.36**	0.35**
λ	0.38**	0.33**	0.38**	0.41**	0.39**	0.34**	0.38**	0.43**	0.54***	0.46**	0.48**	0.5**
$\beta_{lag\ 1}$		0.28**	0.29**	0.24		0.29**	0.3**	0.23		0.36**	0.36**	0.35**
$\lambda_{lag\ 1}$		0.05	-0.02	0.02		0.01	-0.05	-0.01		0.17	0.15	0.16
$\beta_{lag\ 2}$			0.12	0.15			0.10	0.14			0.06	0.05
$\lambda_{lag\ 2}$			0.21	0.17			0.22	0.17			0.06	0.04
$\beta_{lag\ 3}$				0.01				0.03				0.10
$\lambda_{lag\ 3}$				0.24				0.31*				0.04
Total β	0.28	0.52	0.60	0.56	0.25	0.49	0.55	0.52	0.41	0.73	0.78	0.85
Total λ	0.38	0.38	0.57	0.83	0.39	0.35	0.56	0.90	0.54	0.64	0.69	0.74
Nobs.	143	143	143	143	143	143	143	143	143	143	143	143
R^2	0.06	0.09	0.11	0.12	0.06	0.09	0.10	0.12	0.10	0.14	0.14	0.14

Panel B: Quarterly data	**Specification 2**		**Specification 3**			
			Index (without Lafite)		**Lafite index**	
α	2.7%	0.2%	2.5%	0.2%	5.8%	2.0%
β	0.44***	0.33**	0.41***	0.3**	0.53***	0.37**
λ	0.32*	0.46**	0.32*	0.44**	0.48**	0.64***
$\beta_{lag\ 1}$		0.09		0.08		0.25*
$\lambda_{lag\ 1}$		0.34*		0.30		0.33
Total β	0.44	0.41	0.41	0.39	0.53	0.62
Total λ	0.32	0.80	0.32	0.74	0.48	0.97
Nobs.	47	47	47	47	47	47
R^2	0.34	0.40	0.32	0.37	0.35	0.43

Notes: results for models 5 and 6 are reported. Panel A shows the results for monthly data and Panel B is for quarterly data. *, ** and *** indicate significativity at the 10%, 5% and 1%-level. The alpha (α) is annualized.

Table 10: Results of the CAPM and liquidity-augmented CAPM regressions (subsample analysis)

Panel A: Monthly data	**Parker score**		**Sub region**				**Age category**				**Liquidity level**			
	Perfect wines		**Left bank**		**Right bank**		**Old wines**		**Young wines**		**Low**		**High**	
α	8.5%	5.7%	6.8%	5.2%	8.5%	5.7%	9.7%	8.8%	6.3%	4.5%	7.5%	5.0%	6.9%	3.9%
β	0.37**	0.33*	0.36**	0.34**	0.24	0.18	0.28	0.24	0.31**	0.27*	0.32*	0.3*	0.3**	0.27*
λ	0.28	0.20	0.44**	0.4**	0.15	0.08	0.23	0.20	0.41**	0.36**	0.14	0.08	0.35**	0.27
$\beta_{lag\ 1}$		0.33*		0.19		0.41**		0.22		0.27*		0.24		0.33**
$\lambda_{lag\ 1}$		0.16		0.08		0.07		-0.06		0.04		0.17		0.19
Total β	0.37	0.67	0.36	0.53	0.24	0.60	0.28	0.46	0.31	0.54	0.32	0.54	0.30	0.60
Total λ	0.28	0.36	0.44	0.48	0.15	0.15	0.23	0.15	0.41	0.41	0.14	0.25	0.35	0.47
Nobs.	143	143	143	143	143	143	143	143	143	143	143	143	143	143
R^2	0.05	0.07	0.07	0.08	0.02	0.05	0.02	0.02	0.07	0.09	0.03	0.04	0.06	0.10
Panel B: Quarterly data	**Parker score**		**Sub region**				**Age category**				**Liquidity level**			
	Perfect wines		**Left bank**		**Right bank**		**Old wines**		**Young wines**		**Low**		**High**	
α	4.6%	1.5%	2.9%	0.3%	4.1%	2.7%	2.4%	-0.3%	3.4%	1.2%	3.1%	1.0%	4.3%	1.1%
β	0.56***	0.4***	0.5***	0.39***	0.47***	0.39***	0.49***	0.35*	0.51***	0.42***	0.48***	0.36**	0.48***	0.35**
λ	0.07	0.28	0.29*	0.42**	0.12	0.23	0.33	0.52**	0.19	0.31*	0.20	0.37*	0.19	0.35
$\beta_{lag\ 1}$		0.03		0.12		-0.05		-0.01		0.10		-0.05		0.14
$\lambda_{lag\ 1}$		0.54***		0.30		0.34*		0.53*		0.27		0.47**		0.38*
Total β	0.56	0.43	0.50	0.51	0.47	0.34	0.49	0.34	0.51	0.51	0.48	0.31	0.48	0.48
Total λ	0.07	0.82	0.29	0.72	0.12	0.57	0.33	1.05	0.19	0.58	0.20	0.84	0.19	0.73
Nobs.	47	47	47	47	47	47	47	47	47	47	47	47	47	47
R^2	0.32	0.43	0.36	0.42	0.31	0.36	0.22	0.29	0.36	0.41	0.28	0.36	0.26	0.33

Notes: results for models 4 and 6 and for specific wine indices (subsamples) are reported. Perfect wines have received a score of 100/100 from R. Parker; wines from the left bank of the Gironde river are from the Médoc and Graves appellations; those from the right bank come from Saint-Emilion and Pomerol; old (young) wines are from vintages 1981 and before (1982 and after); wines with a low (high) liquidity level correspond to the 30% of the wines that trade the least (most) often. *, ** and *** indicate significativity at the 10%, 5% and 1%-level. The alpha (α) is annualized.

Figure 1: Vintage effect

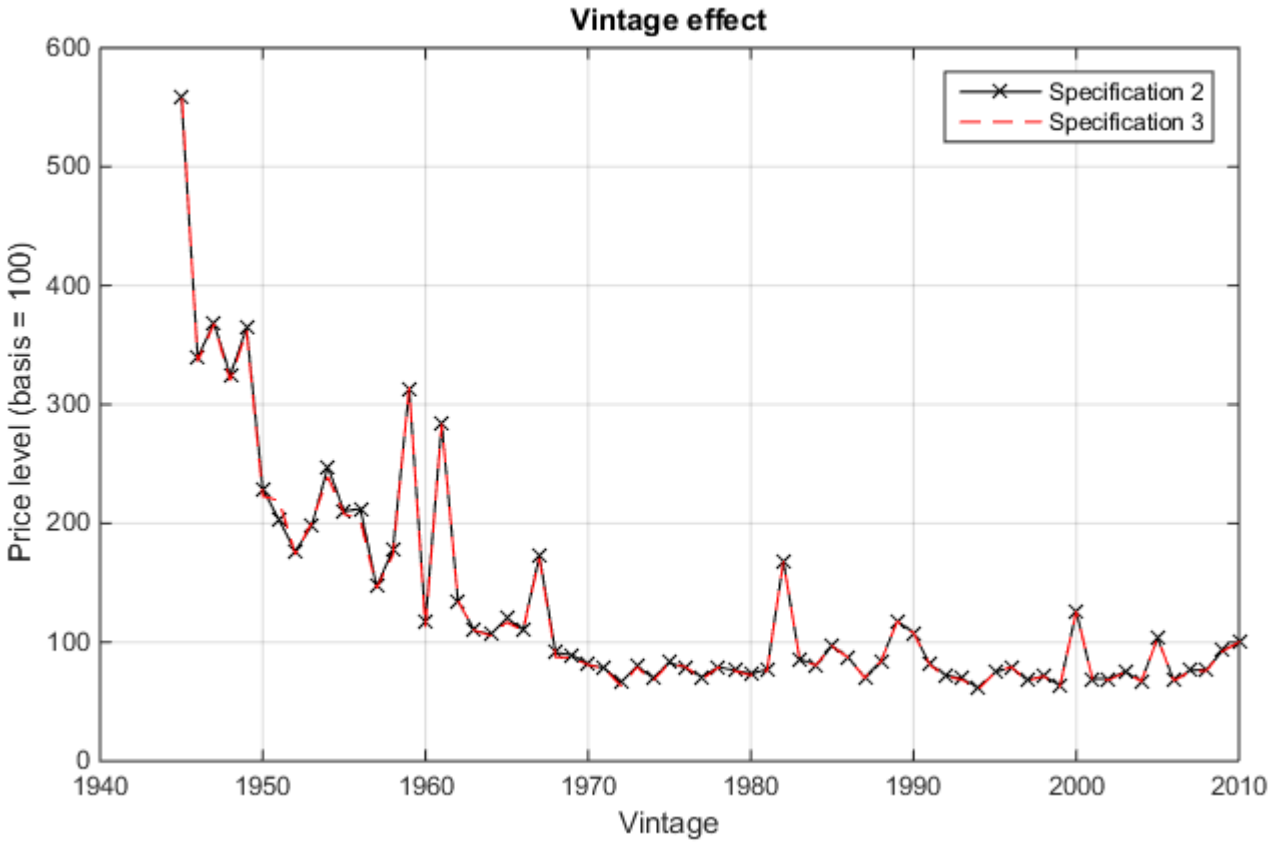

Figure 2: Evolution of the wine index

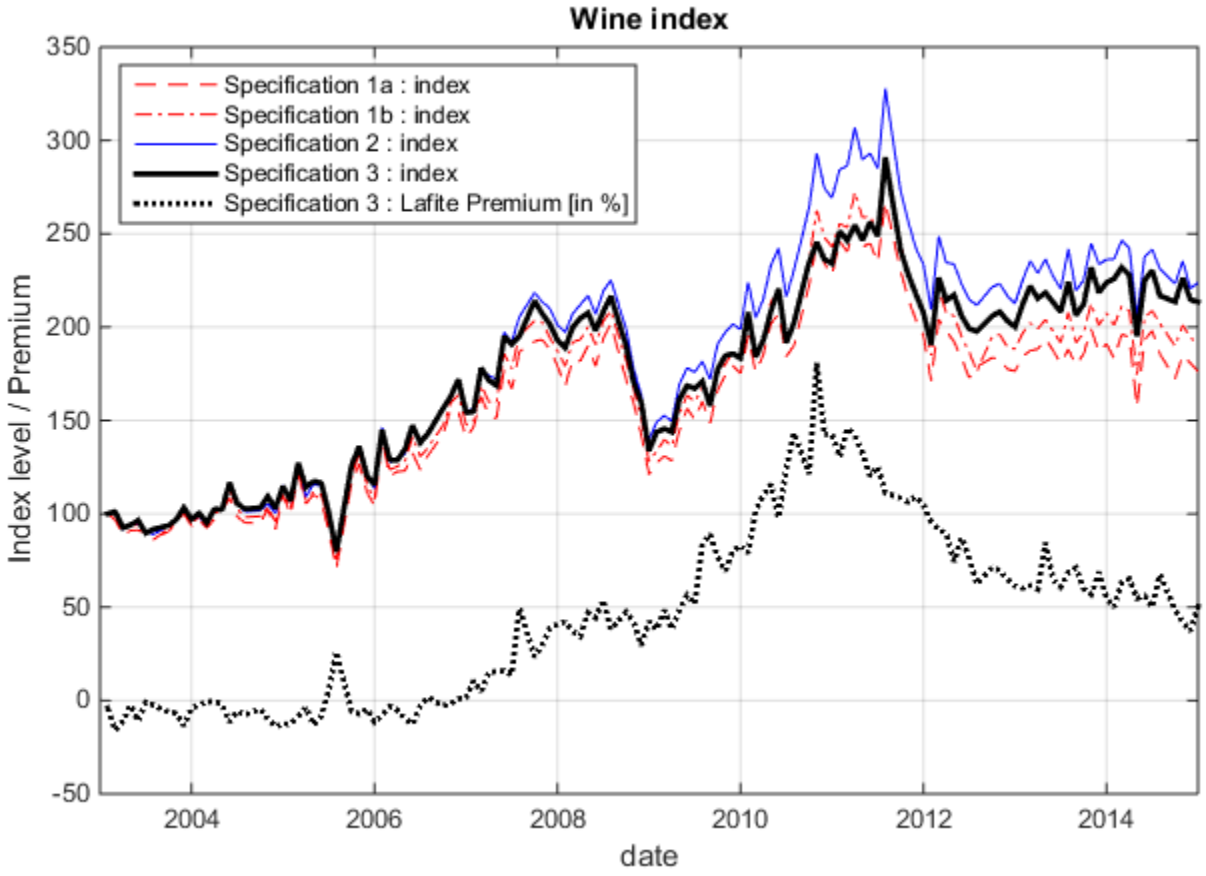

Figure 3: Wine and stock market indices