To Save or Savour: A Review of Wine Investment

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To Save or Savour: A Review of Wine Investment

by

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Abstract

It has been argued that adding wine to an investment portfolio provides a diversification benefit. There is not, however, agreement on how the return to wine should be estimated. Nor is there agreement on a standard approach to test for a diversification benefit. By considering different approaches to estimating the return to wine and testing for a diversification benefit it is shown that claims wine provides a diversification benefit should be treated with caution.

Keywords: Alternative Assets, Portfolio Optimisation

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1 Introduction

The first generation of studies that sought to evaluate the investment potential of wine considered only wine returns, and these studies found mixed evidence regarding the value of wine as an asset class (Krasker 1979; Jaeger 1981; Burton and Jacobsen 2001; Fogarty 2006). A second generation of studies then appeared that considered not only wine return information, but also the potential risk diversification benefit of holding wine, and these studies all found that wine has risk diversification potential (Sanning et al. 2008; Masset and Henderson 2010; Fogarty 2010).

For each study that has estimated the return to wine, Table 1 provides information on the approach taken to estimate returns and the conclusions drawn. As can be seen from the table, the literature has not settled on a standard approach to estimating the return to wine, and the lack of a standard approach means that there remains some uncertainty about the value of wine as an investment good. The following study begins by outlining six different approaches to estimating the return to wine. These approaches have either been used in the literature, are conceptually similar to approaches that have been used in the literature, or are currently used by auction houses. Although the specific context is the return to wine, the explanation of approaches presented serves as a useful reference for all cases where the objective is to estimate the return to infrequently traded heterogeneous assets.

An Australian fine wine sales data set is then used to explore the extent of variation in return to wine estimates due to estimation method selection. In general, the set of wines considered under each approach varies, and so in general, the return and risk estimates obtained using each approach also vary. The evidence presented shows that the choice of estimation method has a significant impact on the estimated risk-return profile of wine, and that unlike standard financial assets, estimates of wine risk and return are sensitive to relatively small changes in the time period considered.

Table 1 **Return to wine literature summary**

No.	Study	Model	Conclusions
1.	Krasker (1979)	Adjacent period repeat sales model	The return to wine is less than the return to Treasury bills. Diversification potential not considered.
2.	Jaeger (1981)	Adjacent period repeat sales model	The return to wine is substantially greater than the return to Treasury bills. Diversification potential not considered.
3.	Burton and Jacobsen (2001)	Repeat sales model	The return to wine is above Treasury bills but below equities. Diversification potential not considered.
4.	Fogarty (2006)	Hedonic model	The return to wine is above Treasury bills but below equities. Diversification potential not considered.
5.	Sanning et al. (2008)	Average of adjacent period returns	Wine provides excess risk adjusted returns, and a risk diversification benefit.
6.	Fogarty (2010)	Repeat sales model	Wine returns are below equities and bonds, but wine provides a risk diversification benefit.
7.	Masset and Henderson (2010)	Weighted average of observed prices	The return to wine is above equities, and wine provides a diversification benefit.
8.	Fogarty and Jones (2011)	Hedonic, repeat sales, and hybrid models	The hybrid model provides the most efficient return estimates. Diversification potential not considered.

Note: The return measure considered is the return to the all wine portfolio reported in each study.

To investigate whether the diversification test chosen plays a role in determining whether holding wine reduces portfolio risk, a variety of different testing approaches are considered. The evidence presented shows that the conclusions drawn about the portfolio diversification benefit attributable to wine depend on: (i) the method used to estimate the return to wine; (ii) the diversification benefit testing approach selected; (iii) the time period considered; and (iv) whether the analysis is conducted in terms of excess returns or raw returns. Taken collectively, the evidence presented suggests that until there is agreement on: (i) a standard approach to estimating the return to wine; and (ii) a standard approach to testing for a diversification benefit from wine, claims that holding wine provides a portfolio diversification benefit should be treated with caution.

2 Return to wine estimation methods

In general, academic economists have favoured regression based methods to estimate the return to wine. From the auction house perspective, regression based approaches to estimating the return to wine have several draw backs; the most prominent of which is that after each auction the entire index needs to be re-estimated, and hence, after each auction there are revisions to historical estimates of the return to wine. For this reason, and the fact that the regression methodology is not widely understood by the general public, auction houses generally rely on non-regression based approaches to estimate the return to wine. Here, the return to wine is estimated using four regression based approaches and two non-regression based approaches. The methods presented have been selected because they either exactly match, or are similar to, the methods that have been used to estimate the return to wine in the academic literature; or they match approaches used by auction houses.

2.1 The hedonic model

Regression model 1 is the hedonic model, and the approach can be understood as follows. Let the time of sale be indexed by t $(t = 0, \dots, T)$, and let the set of all observed wine auction sales be indexed by w $(w = 1, \dots, W)$ so that P_{wt} denotes the price of wine w sold at time t and p_{wt} denotes the log price of wine w sold at time t. Now, let each bottle of wine in the sample be completely described by the attribute set $\{x_k\}$ $(k = 1, \dots, K)$. With this notation the hedonic model can be written as:

$$p_{wt} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kwt} + \sum_{t=1}^{T} \gamma_t d_{wt} + \varepsilon_{wt}, \qquad (1)$$

where d_{wt} is a dummy variable taking the value one if wine w was sold at time t, and zero otherwise. In equation (1) the error term ε_{wt} comprises a random component, and possibly a time independent specification error component. If there is a time independent specification error component it is assumed to be uncorrelated with the x_k. The hedonic model can be estimated via least squares, with the period by period returns calculated from the γ_t estimates. The hedonic model follows from the work of Rosen (1974). A key advantage of the hedonic approach is that it uses all available sales observations. A significant drawback of the approach is that if the hedonic model is misspecified, the estimates of price change are biased (Benkard and Bajari 2005).

2.2 The repeat sales model

Regression model 2 is the repeat sales model due to Bailey et al. (1963), and the approach can be understood as follows. Of the set of all wines sold, a subset will sell on more than one occasion. Let the set of wines that sell more than once be indexed by j, and for wine j let the first sale take place in period *t* and the second sale take place in period τ, where $\tau > t$. Now, for these repeat sale wines re-write equation (1) with the first sale and second sale observations identified separately:

$$p_{jt} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kjt} + \sum_{t=1}^{T} \gamma_t d_{jt} + \varepsilon_{jt}, \tag{2a}$$

$$p_{j\tau} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kj\tau} + \sum_{t=1}^{T} \gamma_t d_{j\tau} + \varepsilon_{j\tau}. \tag{2b}$$

The repeat sales model is found by subtracting (2a) from (2b) to give:

$$p_{j\tau} - p_{jt} = \sum_{t=1}^{T} \gamma_t D_{j\tau} + \varepsilon_{j\tau} - \varepsilon_{jt}, \tag{2c}$$

where $D_{j\tau}$ takes the value one if wine *j* was sold in period τ, minus one if wine *j* was sold in period *t*, and is zero otherwise. As with the hedonic model, the return to wine is calculated from the estimates of γ_t. Unlike the hedonic model there is no potential misspecification problem when using only repeat sales data. However, the approach does not use all available wine sales information. Further, as higher quality vintages trade more frequently (Ashenfelter et al. 1995) there is potentially a sample selection bias with this approach.

2.3 The pooled model

Regression model 3 is the pooled model, where the name is due to the model representing a 'pooling' of the hedonic and the repeat sales models. Although the pooled model has not previously been used to estimate the return to wine, it is an approach similar to the hybrid approach, but computationally much simpler to implement. As such, it is a model worth considering, and the approach can be understood as follows. Let the wines that are sold only once be indexed by i, and again let the repeat sale observations be indexed by j. Now, re-write equation (1) for the full set of wine sale observations such that the single sales, as well as the first and second repeat sales, are identified separately:

$$p_{it} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kit} + \sum_{t=1}^{T} \gamma_t d_{it} + \varepsilon_{it}, \tag{3a}$$

$$p_{jt} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kjt} + \sum_{t=1}^{T} \gamma_t d_{jt} + \varepsilon_{jt}, \tag{3b}$$

$$p_{j\tau} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kj\tau} + \sum_{t=1}^{T} \gamma_t d_{j\tau} + \varepsilon_{j\tau}. \tag{3c}$$

Differencing equation (3b) from equation (3c) gives the repeat sales model:

$$p_{j\tau} - p_{jt} = \sum_{t=1}^{T} \gamma_t D_{j\tau} + \varepsilon_{j\tau} - \varepsilon_{jt}, \tag{3d}$$

and the pooled model is found as equations (3a), (3b), and (3d) stacked in that order, where the covariance matrix used to estimate the model is:

$$\mathbf{\Omega_1} = \sigma_\varepsilon^2 \begin{bmatrix} \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & -\mathbf{I} \\ \mathbf{0} & -\mathbf{I} & 2\mathbf{I} \end{bmatrix}. \tag{3e}$$

As the approach uses all of the data, the pooled model is an improvement on the repeat sales model. The approach does not, however, address the potential misspecification problem in the hedonic model.

2.4 The hybrid model

Regression model 4 is the hybrid model due to Case and Quigley (1991), where the specific implementation of the approach presented here follows Fogarty and Jones (2011). The starting point for the hybrid model is the pooled model, and the difference between the two models is that in the hybrid model the error term ε_{wt} is decomposed into a zero mean constant variance pure random error term denoted e_{wt}, and a zero mean constant variance time independent specification error term denoted η_w. This decomposition of the error term into two parts means that following the same steps as for the pooled model, the hybrid model can be written as:

$$p_{it} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kit} + \sum_{t=1}^{T} \gamma_t d_{it} + \eta_i + e_{it}, \quad (4a)$$

$$p_{jt} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kjt} + \sum_{t=1}^{T} \gamma_t d_{jt} + \eta_j + e_{jt}, \quad (4b)$$

$$p_{j\tau} - p_{jt} = \sum_{t=1}^{T} \gamma_t D_{j\tau} + e_{j\tau} - e_{jt}, \quad (4c)$$

where the covariance matrix used in model estimation is:

$$\mathbf{\Omega_2} = \begin{bmatrix} \sigma_\varepsilon^2 \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \sigma_\varepsilon^2 \mathbf{I} & -\sigma_e^2 \mathbf{I} \\ \mathbf{0} & -\sigma_e^2 \mathbf{I} & 2\sigma_e^2 \mathbf{I} \end{bmatrix}. \quad (4d)$$

Practical model implementation steps are set out in Jones (2010), and Fogarty and Jones (2011). The hybrid model is the most comprehensive regression based approach, and this is its strength. The main disadvantage of the approach is that relative to all other approaches used to estimate the return to wine, estimation is relatively complex.

2.5 The average adjacent period return model

The first non-regression based approach considered is the average adjacent period return model, and if h is used to index the set of wines with adjacent period sales the model can be written as:

$$r_{t+1} = \frac{1}{H} \sum_{h=1}^{H} p_{ht+1} - p_{ht}, \quad (5)$$

where r_{t+1} is the return to wine for period $t + 1$. The approach is simple to implement and understand, but excludes a large proportion of the available information. To the extent that better vintages do trade more frequently, the approach will overstate the return to wine.

2.6 Commercial index model

The final model considered is based on the method used by the Australian wine auction house Langton's, and may be understood as follows. Let P_{lt} denote the price of wine *l* sold at time *t*. If wine l is sold at time $t+1$ then the price observation is updated. If wine l is not sold at time $t+1$ then $P_{lt+1} = P_{lt}$. Letting $\bar{P}_t = \sum_{l=1}^{L} P_{lt}$, the market return to wine at time $t+1$ is found as:

$$r_{t+1} = \log(\bar{P}_{t+1}) - \log(\bar{P}_t). \quad (6)$$

Although the approach is simple to implement and understand, the assumption that if a wine did not sell in a given period the price it would have sold for is the price in the previous period is strong. In practice, the assumption means the approach is likely to understate the true risk associated with wine investment. That the variance of returns is understated, is, however, a criticism that could also be levelled at all regression based approaches.

3 Data and return estimate comparison

The data set used to investigate the impact of estimation method on return calculations consists of 14,102 sale observations on investment grade Australian fine wine sold in Melbourne and Sydney by the Australian auction house Langton's, over the period 1988Q1 to 2000Q4. In the sample, a wine is deemed to be of investment grade if the wine brand is listed in the Caillard and Langton (2001) guide to wine investment in Australia. The specific wine brands in the sample, and the number of times that each wine brand appears in the sample are shown in the appendix. The majority of the wines in the sample (87 percent) are red wines.

The attributes that are assumed to completely describe the sale price of a bottle of wine are: the wine brand (84 individual brands), the wine vintage (years 1965 to 2000), and the time of sale (1988Q1-2000Q4). As such, the specific form equation (1) takes is:

$$p_{wt} = \alpha_0 + \sum_{k=1}^{83} \beta_k x_{kwt} + \sum_{v=1}^{35} \theta_v z_{vwt} + \sum_{t=1}^{51} \gamma_t d_{wt} + \varepsilon_{wt}, \quad (7)$$

where the β_k control for brand differences, the θ_v control for vintage differences, and the γ_t give a log index of the return to wine.

The return information for standard financial assets was obtained from datastream, and it can be noted that for US equities the returns are total returns for the S&P 500; and for Australian equities, returns are total returns for the All Ordinaries Index. Both the Australian and US bond return information relates to the relevant JP Morgan index series. For both US bonds and US equities the returns are unhedged Australian dollar returns.

3.1 Asset return comparison

Table 2 provides summary information on the average return, risk, and return per unit of risk for wine using each estimation approach, and for the four standard financial assets. The upper panel of the table provides raw return information and the lower panel of the table provides excess return information. Excess returns were calculated by subtracting the return available at the start of each quarter from holding 90-day Treasury bills. The summary information is reported for the full sample, for the full sample minus the first five quarters, and the full sample minus last five quarters. As the main research question of interest is the impact estimation method has on the estimated wine return distribution, Figure 1 presents kernel density estimates for the return to wine for each estimation method considered. Complete period-by-period return to wine information is reported in the appendix.

Figure 1 Wine return distribution plots: 1988Q1-2000Q4

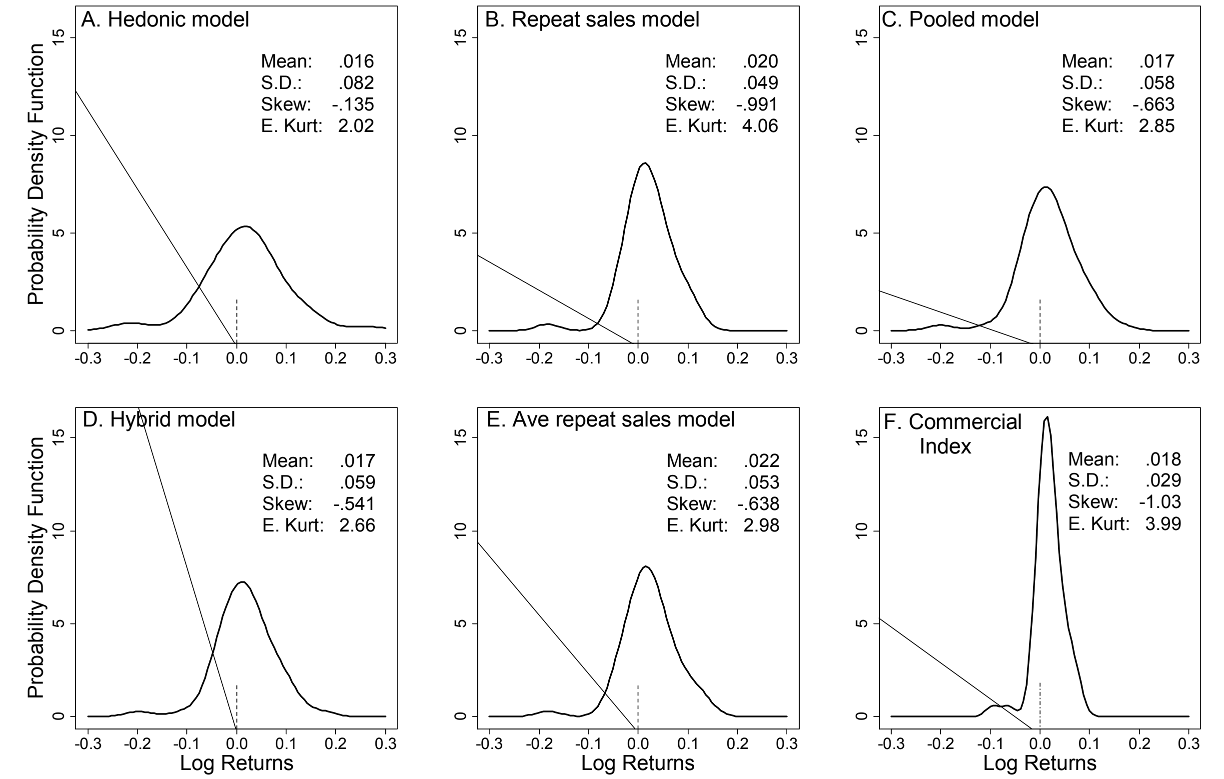


Table 2 **Summary quarterly asset performance information (log returns)**

Asset	1988Q1-2000Q4					1989Q2-2000Q4					1988Q1-1999Q3				
	Log return	St. Dev.	Return/ risk	Skew.	E. Kurt.	Log return	St. Dev.	Return/ risk	Skew.	E. Kurt.	Log return	St. Dev.	Return/ risk	Skew.	E. Kurt.
Panel A. Raw return information															
Wine hedonic model	.016	.082	.199	-.136	2.02	.022	.060	.365	.265	-.361	.018	.086	.211	-.191	1.65
Wine repeat sales model	.020	.049	.397	-.991	4.06	.023	.039	.592	.448	-.337	.022	.051	.427	-1.10	3.87
Wine pooled model	.017	.058	.300	-.663	2.85	.022	.043	.509	.395	-.631	.019	.061	.319	-.734	2.52
Wine hybrid model[1]	.017	.059	.290	-.541	2.66	.021	.044	.487	.377	-.680	.019	.061	.309	-.617	2.33
Wine ave. adjacent return	.022	.053	.414	-.638	2.98	.027	.043	.634	.748	.153	.024	.055	.436	-.734	2.72
Wine commercial index	.018	.029	.596	-1.03	3.89	.022	.022	1.01	.894	-.022	.018	.031	.599	-1.09	3.53
Australian equities	.026	.057	.457	.087	-.733	.026	.058	.446	.059	-.719	.026	.059	.444	.063	-.782
Australian bonds	.027	.030	.906	-.275	-.125	.028	.031	.924	-.386	-.147	.027	.030	.905	-.288	-.132
US equities	.044	.078	.561	-.380	.107	.044	.078	.561	-.463	.300	.044	.077	.575	-.323	.298
US bonds	.025	.061	.412	.217	-.899	.026	.058	.447	.207	-1.05	.022	.061	.358	.245	-.859
Panel B. Excess return information															
Wine hedonic model	-.004	.083	-.043	-.329	1.96	.003	.060	.057	.163	-.213	-.002	.087	-.027	-.358	1.57
Wine repeat sales model	.000	.051	-.005	-1.05	4.26	.005	.040	.118	.502	-.389	.001	.053	.028	-1.11	3.89
Wine pooled model	-.002	.060	-.042	-.802	2.82	.004	.044	.082	.347	-.591	-.001	.063	-.018	-.835	2.41
Wine hybrid model	-.003	.060	-.048	-.691	2.62	.003	.045	.065	.347	-.619	-.001	.063	-.024	-.729	2.23
Wine ave. adjacent return	.002	.055	.039	-.774	2.94	.009	.044	.200	.603	-.132	.004	.057	.065	-.827	2.58
Wine commercial index	-.002	.033	-.070	-1.10	3.18	.004	.024	.155	.465	-.443	-.002	.035	-.057	-1.09	2.68
Australian equities	.006	.059	.108	-.032	-.772	.008	.060	.127	-.096	-.729	.006	.061	.094	-.044	-.835
Australian bonds	.007	.029	.241	-.154	-.507	.010	.029	.343	-.329	-.283	.007	.030	.234	-.137	-.531
US equities	.024	.079	.302	-.443	.333	.025	.079	.318	-.513	.561	.024	.078	.304	-.407	.587
US bonds	.005	.062	.086	.196	-.968	.007	.059	.126	.275	-1.092	.001	.061	.022	.222	-.958

Note: [1] The main advantage of hybrid model relative to the other regression based models is that the standard error bands surrounding each point estimate are smaller. As a means of comparing the estimation results across models it can be noted that the average standard error surrounding each point estimate of price change were as follows: hedonic model .0427, repeat sales model .0533, pooled model .0403, and hybrid model .0325.

Taken collectively, the information presented in Figure 1 and Table 2 suggests the following. First, wine risk, return, and risk adjusted return estimates vary substantially with estimation method. Second, across all wine return estimation methods, relatively small changes in the time period under consideration have a substantial impact on the risk, return, and risk adjusted return estimates, but little impact on the same measures for the four standard financial assets. Third, the return distribution obtained using the commercial index approach is strikingly different to that obtained for all other estimation methods. Fourth, consistent with a sample selection problem, the average adjacent period method always generates the highest mean return estimate, and the repeat sales model always generates the second highest mean return estimate. Fifth, for wine, small changes in the sample period have a relatively significant impact on measures of skew and kurtosis.

Before formally investigating the risk diversification benefits of wine, it is worth considering the linear correlation between asset returns. As such, Table 3 provides information on: (i) the correlation between wine return estimates calculated using different approaches; and (ii) the correlation between the different return to wine estimates and standard financial assets. There are three panels within Table 3, and within each panel the values below the diagonal give the correlation coefficient between asset pairs, and the values above the diagonal give the p-value for a test of the statistical significance of the correlation identified in the corresponding location below the diagonal. How to read the information in the table can be understood by considering a specific example.

First, let the elements in each panel be denoted by, respectively, A_{ii}, B_{ii}, and C_{ii}. Then, in Panel A, by reading down the hedonic column to the hybrid row (element A_{41}) it can be seen that the correlation between the hedonic model return to wine estimates and the return to wine estimates from the hybrid model is .95. By then reading across the hedonic row to the hybrid column (element A_{14}) it can be seen that the p-value for a test of whether or not the correlation between the hedonic model return to wine estimates and the hybrid model return to wine estimates are statistically significant is less than .01.

Table 3 **Asset correlation matrix and associated p-values of significance: raw returns**

	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.	A. equi.	A. Bond	U equi.	U Bond
Panel A. Full sample: 1988Q1-2000Q4										
Wine hedonic model	-	<.01	<.01	<.01	<.01	<.01	.42	.83	.30	.25
Wine repeat sales model	.85	-	<.01	<.01	<.01	<.01	.81	.99	.32	.33
Wine pooled model	.95	.97	-	<.01	<.01	<.01	.57	.95	.29	.28
Wine hybrid model	.95	.96	1.00[1]	-	<.01	<.01	.59	.94	.30	.27
Wine ave. adj. return	.74	.89	.86	.86	-	<.01	.59	.83	.30	.47
Wine commercial index	.56	.72	.69	.68	.82	-	.60	.85	.40	.64
Australian equities	.12	.03	.08	.08	.08	.08	-	.08	<.01	.48
Australian bonds	.03	.00	.01	.01	-.03	.03	.25	-	.08	<.01
US equities	.15	.14	.15	.15	.15	.12	.40	.25	-	<.01
US bonds	.16	.14	.15	.16	.10	.07	-.10	.47	.57	-
Panel B. First five quarters of the sample deleted: 1989Q2-2000Q4										
Wine hedonic model	-	<.01	<.01	<.01	<.01	<.01	.06	.96	.41	.90
Wine repeat sales model	.82	-	<.01	<.01	<.01	<.01	.17	.83	.53	.81
Wine pooled model	.93	.97	-	<.01	<.01	<.01	.08	.80	.44	.90
Wine hybrid model	.93	.97	1.00[1]	-	<.01	<.01	.09	.82	.45	.94
Wine ave. adj. return	.72	.88	.85	.85	-	<.01	.16	.44	.42	.59
Wine commercial index	.60	.73	.72	.72	.75	-	.21	.55	.44	.45
Australian equities	.28	.21	.26	.25	.21	.19	-	.12	<.01	.39
Australian bonds	-.01	-.03	-.04	-.03	-.12	-.09	.23	-	.11	<.01
US equities	.12	.10	.12	.11	.12	.12	.42	.24	-	<.01
US bonds	.02	-.04	-.02	-.01	-.08	-.11	-.13	.48	.51	-
Panel C. Last five quarters of the sample deleted: 1988Q1-1999Q3										
Wine hedonic model	-	<.01	<.01	<.01	<.01	<.01	.50	.80	.30	.16
Wine repeat sales model	.85	-	<.01	<.01	<.01	<.01	.86	.99	.35	.23
Wine pooled model	.95	.97	-	<.01	<.01	<.01	.63	.94	.32	.20
Wine hybrid model	.96	.96	1.00[1]	-	<.01	<.01	.66	.93	.33	.18
Wine ave. adj. return	.74	.89	.86	.86	-	<.01	.63	.84	.34	.35
Wine commercial index	.56	.71	.69	.68	.82	-	.66	.81	.48	.52
Australian equities	.10	.03	.07	.07	.07	.07	-	.03	<.01	.65
Australian bonds	.04	.00	.01	.01	-.03	.04	.31	-	.02	<.01
US equities	.16	.14	.15	.15	.14	.11	.39	.35	-	<.01
US bonds	.21	.18	.19	.20	.14	.10	-.07	.51	.62	-

Note: [1] The main difference between the hybrid model and the pooled model is in terms of estimate efficiency not point estimates of price change.

General observations about the information contained in Table 3 can be made by sequentially considering the blocks identified in each panel of the table. First, by considering the upper left blocks in each panel it can be seen that the correlation between the different wine return estimates is high and statistically significant. Across all models, the weakest correlation is between the returns from the commercial index approach and the other methods. Second, by considering the upper right blocks and lower left blocks of each panel together, it can be seen that the correlation between the return to wine and standard financial assets is low and that the correlations are not statistically significant at the five percent level. Third, by considering the lower right block in each panel it can be seen that with the exception of the correlation between US bonds and Australian equities, the correlations between standard financial assets are positive and statistically significant. Fourth, by considering the respective elements of each panel in the table -- for example A_{13}, B_{13}, C_{13} and A_{31}, B_{31}, C_{31} -- it can be seen that the pair-wise correlations are relatively robust to small changes in the time period considered. The values calculated using excess return information are very similar to the values shown in Table 3, and so are not reported.

4 Diversification benefit tests

A number of different approaches have been used to test for a portfolio diversification benefit from wine. The approaches considered here are either same, or conceptually similar to approaches discussed in the existing return to wine literature. Although most applied financial analysis relies on excess return data, in some cases, such as Jobson (1982), the risk free rate is assumed to be zero. Additionally, some studies in the existing return to wine literature, such as Fogarty (2010), use raw returns to test for a diversification benefit. As such, for each diversification benefit test, the test is conducted using both raw return data and excess return data. Additionally, as the returns analysis revealed that the mean return to wine estimate can vary significantly with the time period under investigation, for each diversification benefit test the analysis is undertaken using: (i) the full data set; (ii) the full data set minus the first five quarters; and (iii) the full data set minus the last five quarters.

4.1 Diversification benefit test 1

The first approach to testing for a diversification benefit is based on the approach outlined in Jobson (1982). The Jobson approach uses an *F*-test to compare the performance of a portfolio containing only a subset of assets against a portfolio that can contain a wider set of assets. Within the Jobson framework, a portfolio is said to be market efficient if the ratio μ^2/σ^2 is maximised, where μ denotes portfolio return and σ^2 denotes portfolio variance. If $\boldsymbol{u}$ is used to denote the mean return vector for the full set of assets, and $\boldsymbol{V}$ is used to denote the associated sample covariance matrix, under conditions of no short selling and a fully invested portfolio the maximum value of the ratio μ^2/σ^2 is given by $\boldsymbol{u}'\boldsymbol{V}^{-1}\boldsymbol{u}$. If $\boldsymbol{u_r}$ and $\boldsymbol{V_r}$ are used to denote, respectively, the mean return vector and associated sample covariance matrix for the restricted portfolio containing only a subset off assets, the Jobson test can be understood as a test of the hypothesis that $\boldsymbol{u}'\boldsymbol{V}^{-1}\boldsymbol{u} = \boldsymbol{u}_r'\boldsymbol{V}_r^{-1}\boldsymbol{u}_r$. Following Jobson (1982) the test is implemented as an F-test.

A summary of the F-test results is provided in Table 4, where the values in the table are *p*-values. A low *p*-value implies that it is possible to reject the null hypothesis of no portfolio performance improvement following the addition of wine to the portfolio with relative confidence. The basic implication of the information reported in Table 4 is that the conclusion drawn about the ability of wine to improve portfolio performance is sensitive to: (i) the estimation method used to calculate the return to wine; (ii) the time period considered; and (iii) whether the test is conducted using raw return information or excess return information.

Table 4 **Summary results for diversification benefit test one (*p*-values)**

Sample period	Raw returns						Excess returns					
	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.
Period: 1988Q1-2000Q4	.471	.081	.204	.218	.057	.014	.790	.921	.763	.747	.856	.486
Period: 1989Q2-2000Q4	.177	.019	.037	.050	<.01	<.01	.589	.393	.486	.553	.167	.337
Period: 1988Q1-1999Q3	.025	<.01	<.01	<.01	<.01	<.01	.914	.914	.914	.920	.593	.674

4.2 Diversification benefit test 2

The second approach to testing for a diversification benefit is based on an approach outlined in both Blume (1984) and Elton et al. (1987). In this instance the approach is used to test whether there is a diversification benefit from adding wine to a portfolio consisting of an equally weighted portfolio of the four standard assets identified in Table 2. Under this testing approach, the portfolio investment objective is to maximise return per unit of risk, and following the Elton et al. (1987) form of the test, if the return per unit of risk for wine (r_w/σ_w) is greater than the return per unit of risk for the existing market portfolio multiplied by the correlation coefficient between the portfolio and wine $(r_p/\sigma_p)\rho_{wp}$, there is a diversification benefit from adding wine to the market portfolio. This decision rule follows from the conditions for the inclusion of an asset in the optimal portfolio established in Elton et al. (1976).

Table 5 contains summary testing results where the specific values reported in the table are $(r_w/\sigma_w) - (r_p/\sigma_p)\rho_{wp}$, so that positive values indicate a diversification benefit from adding wine to the portfolio and negative values indicate no diversification benefit. The results in Table 5 show that for the Elton et al. approach to testing for a diversification benefit from holding wine, the conclusions drawn are sensitive to: (i) whether or not the analysis is conducted in terms or raw returns or excess returns; (ii) the estimation method used to calculate the return to wine; and (iii) the time period considered.

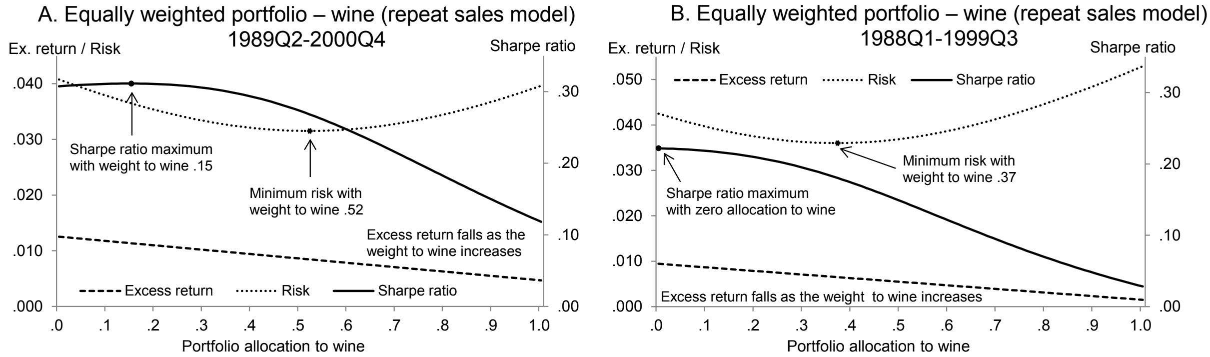
Table 5 **Summary results for diversification benefit test two**

Sample period	Raw returns						Excess returns					
	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.
Period: 1988Q1-2000Q4	.178	.063	.296	.168	.314	.509	-.098	-.050	-.096	-.101	-.009	-.125
Period: 1989Q2-2000Q4	.400	.231	.510	.380	.566	.953	-.004	.073	.025	.010	.160	.104
Period: 1988Q1-1999Q3	.197	.072	.325	.188	.336	.516	-.078	-.013	-.067	-.072	.021	-.105

Note: For all return to wines series, the correlation to an equally weighted portfolio of standard financial assets is never statistically different from zero. Assuming the correlation coefficient is zero leaves the key result that conclusions about the diversification benefit of wine are sensitive to: the use of raw returns versus excess returns, the return to wine estimation method selected, and the time period considered, unchanged.

The drivers of the test results are not necessarily clear from the decision rule formula, and so it is worth illustrating the operation of the test with an example. From Table 5 it can be seen that for the repeat sales model, when using excess return data, the decision rule says that for the period 1989Q2-2000Q4 there is a diversification benefit from adding wine to an equally weighted portfolio of standard financial assets, but for the period 1988Q1-1999Q3 there is no diversification benefit. The reason for this finding can be seen by considering Figure 2, which plots excess return, risk, and the excess return per unit of risk information for a series of portfolios created by incrementally adding wine to an equally weighted portfolio of the four standard financial assets. The plot on the left is for the period 1989Q2-2000Q4, and the plot on the right is for the period 1988Q1-1999Q3. In each plot the values at the extreme left are for portfolios fully invested in the equally weighted portfolio of standard financial assets, and the values at the extreme right are values for portfolios fully invested in wine. As can be seen, for the period 1989Q2-2000Q4, when wine is added to the portfolio of standard financial assets, at first, risk falls faster than portfolio return; hence the decision rule conclusion that there should be a positive allocation to wine. For the period 1988Q1-1999Q3, when wine is added to the portfolio of standard financial assets, the portfolio return always falls faster than portfolio risk; hence the decision rule conclusion that wine should not be added to the portfolio. The visual approach to explaining the Elton et al. diversification benefit test follows Polwitoon and Tawatnuntachai (2008).

Figure 2 Illustration of diversification benefit test



4.3 Diversification test 3

The third approach to testing for a risk diversification benefit is the mean-variance spanning approach. When considering the addition of a single asset class to an existing investment portfolio an appropriate mean-variance spanning test is the Huberman and Kandel (1987) regression based test. In this instance the test involves regressing the return to wine from each estimation method on the return to the assets already in the investment portfolio, and an intercept term. In such a regression, if the intercept is zero, and the sum of the point estimates on the other asset classes is one, the conclusion drawn is that the return to wine can be synthetically reproduced by a weighted sum of the assets already in the investment portfolio, and the return to wine is said to be spanned by the existing assets. If the return to the test asset can be synthetically reproduced by the assets already in an investment portfolio the test asset is not added to the portfolio.

The Huberman and Kandel mean-variance spanning regression was estimated using the quarterly return information summarised in Table 2. The form of the spanning test regression is $\ddot{r}_{jt} = \alpha + \sum_{i=1}^{K} \beta_i r_{it} + u_{jt}$, where $\ddot{r}_{jt}$, denotes the return to wine from estimation method j at time *t*; r_{it} denotes the return to benchmark asset *i* at time *t*, where the benchmark assets are the same assets used in the earlier tests, and u_{jt} denotes a zero mean constant variance error term. The joint constraint that $\sum_{i=1}^{K} \beta = 1$ and $\alpha = 0$ is then imposed via a Wald-test.

Prior to considering the results, which are reported in Table 6, it is worth noting an alternate interpretation of the mean-variance spanning regression test. As shown in Kan and Zhou (2001), the mean-variance spanning test described above is a joint test that there is zero allocation to wine in the minimum variance portfolio ($\sum_{i=1}^{K} \beta_i = 1$) and the tangency portfolio ($\alpha = 0$). If there is zero allocation to wine in these two portfolios, it then follows from the two fund separation theorem that the asset wine would not be included in any portfolio. Given this alternate explanation of the testing approach, reporting on the restrictions individually, as well as jointly, provides meaningful additional information. As such, Table 6 reports *p*-values for the tests that: the intercept is zero; at least one of the β_i is statistically significant; the β_i sum to one; and the joint restriction that the intercept is zero and the β_i sum to one.

In contrast to the two previous testing approaches, the core conclusions drawn about the diversification benefit of wine when using a mean-variance spanning test are not influenced by whether or not the analysis is undertaken using excess returns or raw returns. However, as can be seen from the values reported in Table 6, the conclusion drawn about whether or not wine provides a diversification benefit varies depending on the time period considered, and the method used to estimate the return to wine.

Considering the individual restriction information, it can also be seen that for all approaches to estimating the return to wine, and across all time periods, it is not possible to reject the null hypothesis that all β_i are zero. Given the lack of correlation between the return to wine and standard financial assets reported in Table 3, this finding is not surprising. It can also be seen that the evidence against the null of zero allocation to wine in the minimum variance portfolio is always stronger than the evidence against a zero allocation to wine in the tangency portfolio.

Table 6 **Summary results for diversification benefit test three (*p*-values)**

Hypothesis tested	Raw returns						Excess returns					
	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.	Hedonic	Repeat	Pooled	Hybrid	Ave. adj.	Comm.
Panel A. Full sample: 1988Q1-2000Q4												
$\alpha = 0$	.466	.199	.078	.213	.055	.013	.788	.920	.760	.744	.854	.481
$\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$	.610	.705	.824	.698	.785	.946	.475	.685	.533	.532	.628	.653
$\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$	.065	<.01	<.01	<.01	<.01	<.01	.094	<.01	<.01	<.01	<.01	<.01
$\alpha = 0$ and $\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$	.145	<.01	<.01	<.01	<.01	<.01	.195	<.01	.019	.019	<.01	<.01
Panel B. First five quarters of the sample deleted: 1989Q2-2000Q4												
$\alpha = 0$	.136	.026	.034	.011	<.01	<.01	.584	.387	.481	.548	.162	.331
$\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$	.336	.426	.469	.693	.499	.585	.195	.403	.205	.234	.257	.296
$\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$	.012	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
$\alpha = 0$ and $\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$	.039	<.01	<.01	<.01	<.01	<.01	.027	<.01	<.01	<.01	<.01	<.01
Panel C. Last five quarters of the sample deleted: 1988Q1-1999Q3												
$\alpha = 0$	.337	.128	.136	.044	.035	.014	.922	.731	.913	.919	.588	.670
$\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$	.475	.567	.549	.680	.675	.949	.375	.555	.435	.424	.541	.680
$\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$	.079	<.01	<.01	<.01	<.01	<.01	.118	<.01	.013	.013	<.01	<.01
$\alpha = 0$ and $\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$	.206	.018	.020	<.01	<.01	<.01	.285	<.01	.041	.041	.013	<.01

4.4 Diversification test 4

The fourth approach to investigating the potential of wine to provide a risk diversification benefit is the direct estimation of the mean-variance efficient frontier under conditions of no short selling and a fully invested portfolio. The base case results presented represent the classic Markowitz (1952) model, where the sample covariance matrix $\boldsymbol{V}$ and the mean return vector $\boldsymbol{u}$ are used in the optimisation model.

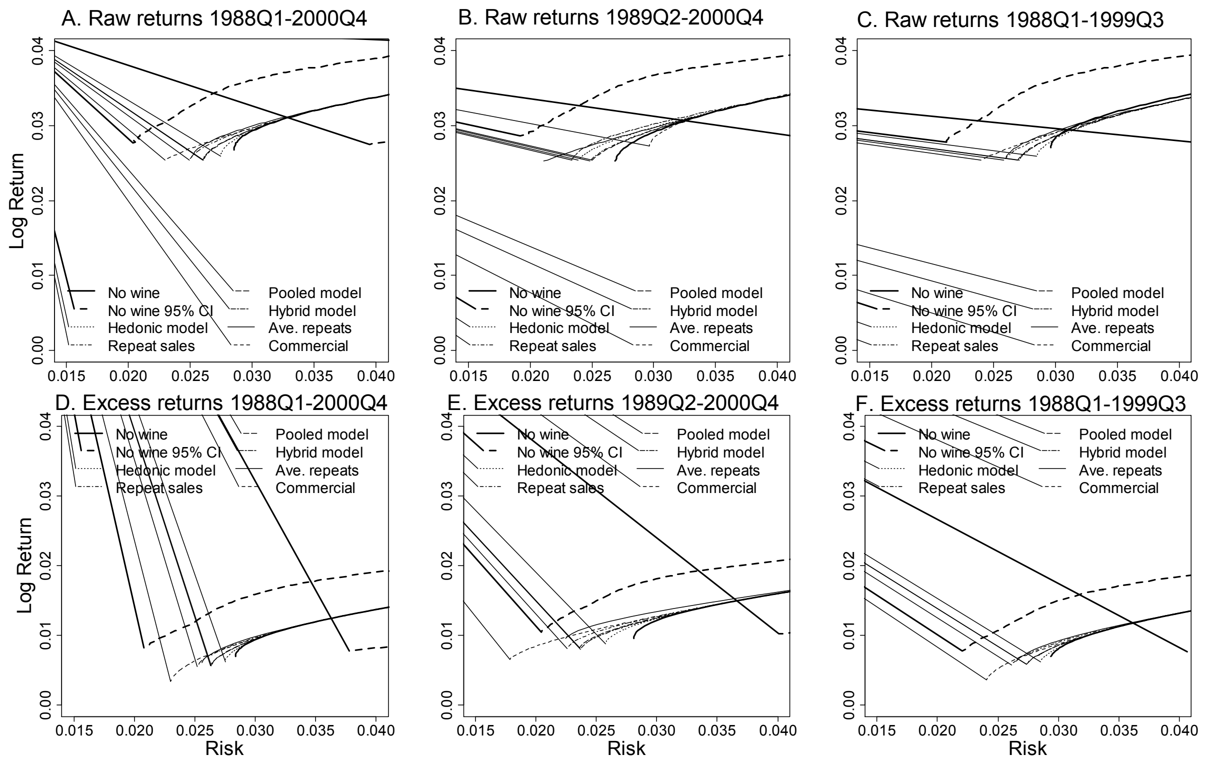
The results of this approach are summarised in Figure 3, and the process for generating the plots can be understood as follows. First, for the three time periods considered the efficient frontier was estimated using both raw return data and excess return data with the allocation to wine restricted to zero. These six efficient frontiers were then plotted in risk return space. For each of the six scenarios considered a 95 percent confidence interval was obtained via circular block bootstrapping to account for time series dependence in the asset returns (Politis and Romano 1992). Here we chose a block size that is optimal for constructing a confidence interval for the Sharpe ratio, using the method of Ledoit and Wolf

(2008). This optimal block size for the Sharpe ratio was then applied to the data to generate the block bootstrap samples for computing confidence intervals on the risk efficient frontier.

Finally, using both raw return and excess return data, for each return to wine series × time period the efficient frontier was calculated where a positive allocation to wine was allowed. These efficient frontiers were then added to each plot. If there are efficient portfolios with a positive allocation to wine that achieve the same level of return as a no wine portfolio with lower risk, then wine is said to provide a diversification benefit. If the expansion of the efficient frontier extends beyond the 95 percent bootstrap confidence bound, the benefit is said to be statistically significant.

As can be seen from the plots, in all cases considered a positive allocation to wine allows the efficient frontier to shift to the left; although in most case the shift is quite small. Consistent with the findings reported in Table 6, the potential benefit due to holding wine is for portfolios near the GMV portfolio. The potential diversification benefit due to holding wine, is, however, almost always found to be not statistically significant. The only exception to this is the efficient frontier constructed using the commercial index method when the first five quarters are dropped from the sample.

Figure 3 Statistical significance of the shift in the efficient frontier: Markowitz model



4.5 Efficient frontier sensitivity analysis

Many modifications to the classic Markowitz approach to deriving the efficient frontier have been proposed. Here the impact of: (i) using a shrinkage estimator for the mean return vector; (ii) using a shrinkage estimator for the covariance matrix; and (iii) considering higher order moments is explored. In this analysis the main element of interest is the sensitivity of the weight to wine in efficient portfolios.

The first scenario considered is the use of a shrinkage estimator for the mean return vector. Specifically, the Jorion (1985) return vector is calculated as $\boldsymbol{r} = \alpha\ddot{\boldsymbol{u}} + (1-\alpha)\boldsymbol{u}$, where $\ddot{\boldsymbol{u}}$ is a vector with all elements equal to the return of the global minimum variance portfolio, $\boldsymbol{u}$ is the mean return vector, and the weights α are determined by the data. As a practical matter it can be noted that the weight given to $\ddot{\boldsymbol{u}}$ increases the closer $\ddot{\boldsymbol{u}}$ is to $\boldsymbol{u}$.

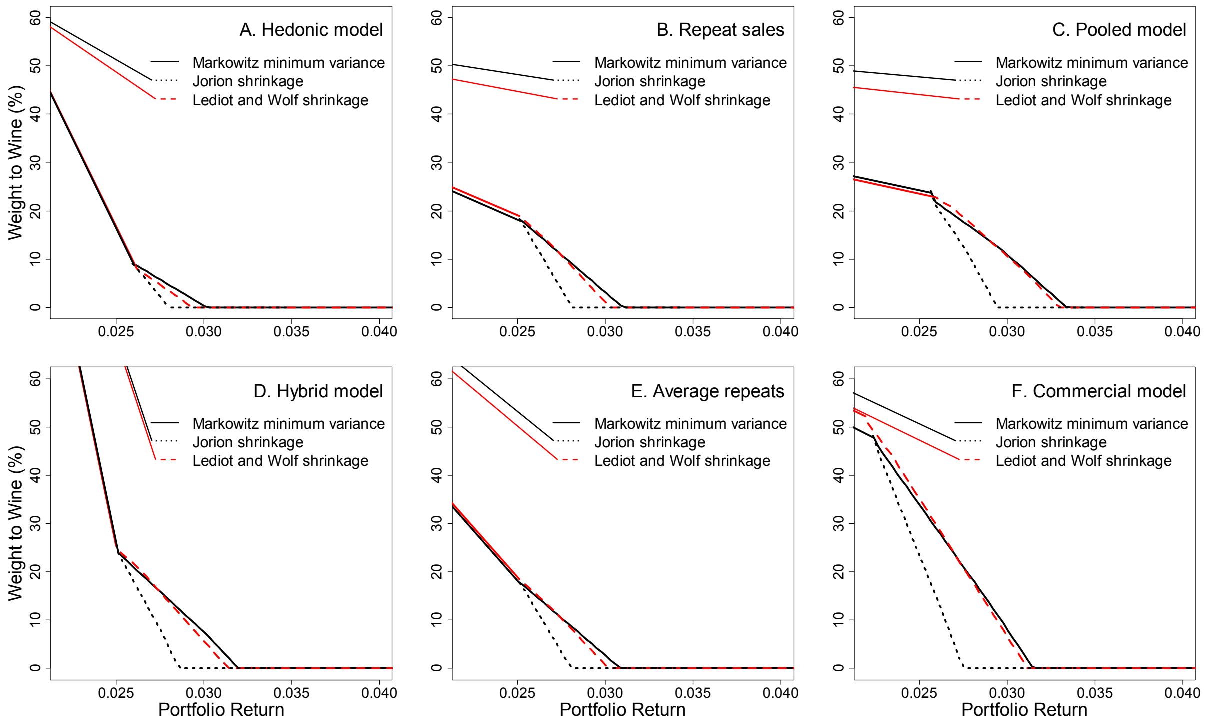
The second scenario considered is the use of a shrinkage estimator for the covariance matrix. Specifically, the Ledoit and Wolf (2004) shrinkage covariance matrix is found as

$\ddot{\boldsymbol{V}} = \frac{k}{T}\boldsymbol{F} + \left(1 - \frac{k}{T}\right)\boldsymbol{V}$, where $\boldsymbol{F}$ is the single-index model covariance matrix of Sharpe (1963), T is the length of the time series, and k is the shrinkage constant. Similar to Jorion's approach for the mean return vector, the shrinkage constant, and hence the weights, are determined by the data. It can be noted that the shrinkage constant, and hence weight to $\boldsymbol{F}$, increases with error in the sample covariance matrix, and decreases with misspecification error in the single index model (Ledoit and Wolf 2004).

The impact on the allocation to wine in efficient portfolios when the mean return vector and the covariance matrix are replaced with shrinkage estimators is illustrated in Figure 4. Specifically, Figure 4 plots the weight to wine in efficient portfolios calculated using the Markowitz method, the Jorion method, and the Lediot and Wolf method. The figure shows that regardless of changes in the method used to estimate the covariance matrix and mean return vector there are still a range of portfolios that have a positive allocation to wine for all methods of calculating the return to wine.

For the sample data, use of the Ledoit and Wolf (2004) covariance matrix has little impact on the weight to wine in efficient portfolios. The reason for the lower weight to wine in efficient portfolios with the Jorion estimator for the mean return vector can be understood as follows. The practical effect of the Jorion estimator is to reduce the estimate of the expected return available from the best performing asset classes and increase the estimate of the expected return available from the worst performing asset classes. The rank order of asset performance is, however, unchanged; hence wine is still always the asset with the lowest return. As such, to achieve a given level of portfolio return, a greater proportion of the total portfolio must be allocated to non-wine assets.

Figure 4 Impact of using shrinkage estimators on portfolio attributes



The final aspect considered is whether the inclusion of higher order moments in the investment optimisation problem impacts the allocation to wine in efficient portfolios. The specific question of interest is whether or not considering higher order moments would cause the allocation to wine in optimal portfolios to fall to zero.

The technique of Polynomial Goal Programming can be used to solve multiple objective investment problems (Lai et al. 2006). However, a problem with such approaches is that the weight given to each objective -- Return, Variance, Skew, Kurtosis -- is arbitrary. Here the approach taken has been to use the insight of the PGP approach regarding the way the classic Markowitz model can be reformulated as a goal programming problem, and then solve a series of mean-variance, mean-skew, and mean-kurtosis optimisation problem. By considering the weight to wine in the optimal portfolio derived using each specification it is possible to develop a solid qualitative understanding of the impact considering higher order moments has on the weight to wine in efficient portfolios.

Recall that the classic the Markowitz efficient frontier for a fully invested portfolio with no short selling can be found by repeatedly solving:

$$\begin{aligned} &\min.\ \mathbf{w}'\mathbf{V}\mathbf{w} \\ &\text{s.t.}\ \mathbf{w}'\boldsymbol{u} = R_P \\ &\mathbf{w} \geq \mathbf{0} \\ &\mathbf{i}'\mathbf{w} = 1 \end{aligned} \tag{8}$$

where, in equation (8) $\mathbf{i}$ is an $N \times 1$ vector of ones, $\mathbf{w}$ is an $N \times 1$ vector with elements w_i equal to the weight to asset i, and R_P is some suitably chosen minimum portfolio return less than the maximum portfolio return achievable, which once set is varied upwards in increments until $R_P = R_P^*$, where R_P^* is the return achievable from the portfolio fully invested in the asset with the highest return. Using Lai et al. (2006) as the basic inspiration for the optimisation models considered, we reformulate (8) to consider mean-skew optimal portfolios and mean-kurtosis optimal portfolios using, respectively:

$$\begin{aligned} &\max.\ \mathbf{w}'\mathbf{S}\mathbf{w} \otimes \mathbf{w} \\ &\text{s.t.}\ \mathbf{w}'\boldsymbol{u} = R_P \\ &\mathbf{w} \geq \mathbf{0} \\ &\mathbf{i}'\mathbf{w} = 1 \end{aligned} \tag{9}$$

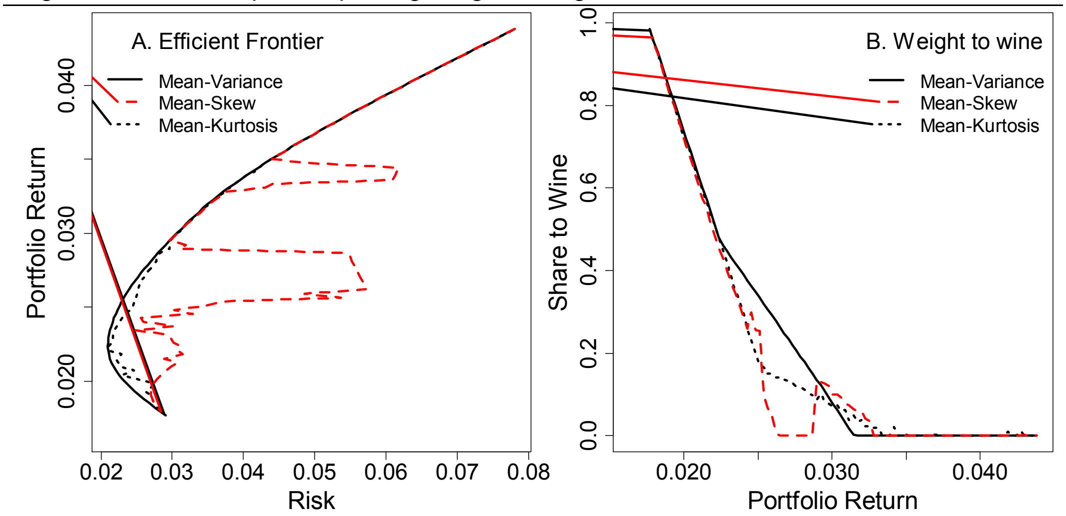
and:

$$\begin{aligned} &\min.\ \mathbf{w}'\mathbf{K}\mathbf{w} \otimes \mathbf{w} \otimes \mathbf{w} \\ &\text{s.t.}\ \mathbf{w}'\boldsymbol{u} = R_P \\ &\mathbf{w} \geq \mathbf{0} \\ &\mathbf{i}'\mathbf{w} = 1 \end{aligned} \tag{11}$$

where the elements of $\boldsymbol{S}$ are found as $s_{ijk} = \left((r_i - \bar{r}_i)(r_j - \bar{r}_j)(r_k - \bar{r}_k)\right)$ and the elements of $\boldsymbol{K}$ are found as $k_{ijkl} = \left((r_i - \bar{r}_i)(r_j - \bar{r}_j)(r_k - \bar{r}_k)(r_l - \bar{r}_l)\right)$.

In Figure 5 we plot the solutions to each optimisation problem in risk-return space and also show the weight to wine in efficient portfolios. As it was difficult to obtain stable solutions we show only the results for the full sample using the Commercial index wine return series. The Commercial index series was chosen for illustration purposes as the series has the most negative skew values and almost the highest kurtosis values. Despite instability problems with the solutions, the result still allow the key issue to be answered, which is that should investors care about higher order moments there is still a positive allocation to wine in some efficient portfolios.

Figure 5 The impact of placing weight on higher order moments



5 Conclusions

Recent papers have argued that adding wine to an investment portfolio provides a diversification benefit. There is, however, no uniform approach to estimating wine returns, and no uniform approach to testing for a diversification benefit from holding wine. Here, six different approaches to estimating wine returns used in the academic literature or by commercial auction houses were explained. A data set of Australian wine sales was then used to show that: (i) estimation method has a material effect of the estimated risk and return associated with holding wine; and (ii) relatively small changes in the time period considered can have a material impact on the estimated return to wine.

A range of approaches to testing for a diversification benefit from holding wine were then considered. The analysis showed that the conclusion drawn about whether holding wine provides a diversification benefit varies with: (i) the method used to estimate the return to wine; (ii) the time period considered; (iii) whether raw return data or excess return data is used; and (iv) the type of diversification test considered. Combined, the evidence suggests that investors should be treat claims that wine provides a diversification benefit with caution.

Table A1 **Specific wine brands and number of times they appear in the sample**

Obs.	Wine brand	Obs.	Wine brand
5,314	*Shiraz dominant*	*5,942*	*Cabernet dominant*
1,139	Penfolds Bin 95 Grange, Shiraz	532	Penfolds Bin 707, Cabernet Sauvignon
724	Penfolds St Henri, Shiraz-Cabernet	521	Wynns Coonawarra Estate, Cabernet Sauvignon
522	Penfolds Bin 389, Shiraz	462	Mount Mary Quintet, Cabernet Blend
448	Henschke Hill of Grace, Shiraz	444	Lake's Folly White Label, Cabernet Blend
312	Henschke Mount Edelstone, Shiraz	328	Wynns John Riddoch, Cabernet Sauvignon
239	Penfolds Magill Estate, Shiraz	319	Lindemans St. George, Cabernet Sauvignon
231	Lindemans Limestone Ridge, Shiraz-Cabernet	316	Yarra Yering No. 1, Cabernet Sauvignon
137	Hardys Eileen Hardy, Shiraz	304	Wolf Blass Black Label, Cabernet Blend
134	Jasper Hill Georgia's Paddock, Shiraz	282	Virgin Hills, Cabernet-Shiraz-Merlot-Malbec
132	Jim Barry The Armagh, Shiraz	275	Moss Wood, Cabernet Sauvignon
127	St. Hallett Old Block, Shiraz	231	Petaluma Coonawarra, Cabernet-Merlot
127	Craiglee, Shiraz	217	Henschke Cyril Henschke, Cabernet Sauvignon
116	Yarra Yering No. 2, Shiraz	174	Lindemans Pyrus, Cabernet Blend
108	Dalwhinnie, Shiraz	153	Taltarni, Cabernet Sauvignon
105	Mount Langi Ghiran Langi, Shiraz	151	Redbank Sally's Paddock, Cabernet Blend
101	Bowen Estate, Shiraz	150	Bowen Estate, Cabernet Sauvignon
80	Jasper Hill Emily's Paddock, Shiraz-Cab. Franc	133	Leconfield, Cabernet Sauvignon
74	Wendouree, Shiraz	130	Orlando St. Hugo, Cabernet Sauvignon
65	Cape Mentelle, Shiraz	122	Leeuwin Estate Art Series, Cabernet Sauvignon
62	Barossa Valley Estate E & E Black Pepper, Shiraz	92	Dalwhinnie, Cabernet Sauvignon
60	Orlando Lawsons, Shiraz	91	Vasse Felix, Cabernet Sauvignon
48	Peter Lehmann Stonewell, Shiraz	88	Seppelt Dorrien, Cabernet Sauvignon
42	Charles Melton Nine Popes, Shiraz Blend	86	Howard Park, Cabernet-Merlot
40	Wendouree, Shiraz-Mataro	83	Yeringberg, Cabernet Blend
40	Coriole Lloyd Reserve, Shiraz	77	Katnook Estate, Cabernet Sauvignon
33	Tyrrell's Vat 9, Shiraz	56	Wendouree, Cabernet-Malbec
28	Elderton Command, Shiraz	54	Wendouree, Cabernet Sauvignon
25	Wendouree, Shiraz-Malbec	50	Plantagenet, Cabernet Sauvignon
15	Seppelt Great Western, Shiraz	21	Xanadu Reserve, Cabernet Sauvignon
1,417	*Chardonnay*	*595*	*Pinot Noir*
332	Tyrrell's Vat 47,Chardonnay	109	Bannockburn, Pinot Noir
225	Mount Mary, Chardonnay	33	Bass Phillip Premium, Pinot Noir
188	Leeuwin Estate Art Series, Chardonnay	47	Giaconda, Pinot Noir
175	Petaluma, Chardonnay	236	Mount Mary, Pinot Noir
139	Lake's Folly Yellow Label, Chardonnay	59	Coldstream Hills Reserve, Pinot Noir
83	Bannockburn, Chardonnay	111	Yarra Yering, Pinot Noir
66	Pierro, Chardonnay	*325*	*Riesling Dominant*
60	Mountadam, Chardonnay	30	Grosset Watervale, Riesling
54	Coldstream Hills Reserve, Chardonnay	52	Grosset Polish Hill, Riesling
48	Giaconda, Chardonnay	149	Petaluma, Riesling
29	Cape Mentelle, Chardonnay	94	Pipers Brook Vineyard, Riesling
18	Cullen, Chardonnay	*174*	*Merlot dominant*
293	*Semillon*	144	Cullen, Merlot-Cabernet
110	De Bortoli Noble One, Botrytis Semillon	30	Irvine Grand, Merlot
183	Tyrrell's Vat 1, Semillon		

Table A2 **Complete model estimation results: 1988Q1-2000Q4**

Time	Regression based approaches								Non-regression approaches	
	Hedonic model		Repeat sales		Pooled model		Hybrid model		Ave. adj. sales	Commercial index
	est.	SE	est.	SE	est.	SE	est.	SE		
1988Q1	1.000		1.000		1.000		1.000		1.000	1.000
1988Q2	.778	(.054)	.817	(.039)	.801	(.045)	.803	(.035)	.818	.903
1988Q3	1.044	(.074)	.926	(.047)	.961	(.048)	.974	(.047)	.918	.920
1988Q4	.840	(.049)	.887	(.041)	.859	(.044)	.870	(.034)	.883	.909
1989Q1	.877	(.044)	.926	(.041)	.885	(.043)	.895	(.033)	.827	.845
1989Q2	.827	(.046)	.939	(.043)	.873	(.044)	.887	(.034)	.876	.875
1989Q3	.968	(.046)	1.016	(.044)	.966	(.044)	.976	(.034)	1.000	.931
1989Q4	1.009	(.043)	1.056	(.044)	.999	(.043)	1.016	(.033)	1.011	.952
1990Q1	.924	(.042)	1.049	(.045)	.963	(.043)	.981	(.032)	1.019	.958
1990Q2	.957	(.050)	1.070	(.049)	.984	(.045)	.997	(.036)	1.000	.953
1990Q3	.987	(.043)	1.086	(.049)	1.000	(.044)	1.012	(.032)	.972	.958
1990Q4	.909	(.041)	1.076	(.048)	.963	(.044)	.976	(.032)	1.004	.961
1991Q1	.896	(.046)	1.065	(.050)	.947	(.045)	.958	(.034)	1.018	.959
1991Q2	.935	(.043)	1.065	(.050)	.958	(.044)	.974	(.033)	1.027	.971
1991Q3	.937	(.045)	1.104	(.052)	.985	(.045)	1.002	(.033)	1.055	.982
1991Q4	1.015	(.043)	1.128	(.052)	1.022	(.044)	1.034	(.033)	1.057	1.008
1992Q1	.933	(.043)	1.114	(.052)	.991	(.043)	.997	(.033)	1.080	1.021
1992Q2	.983	(.044)	1.151	(.053)	1.024	(.044)	1.033	(.033)	1.168	1.034
1992Q3	.926	(.049)	1.099	(.055)	.970	(.045)	.979	(.035)	1.127	1.032
1992Q4	1.034	(.043)	1.169	(.058)	1.048	(.045)	1.061	(.033)	1.187	1.056
1993Q1	.957	(.044)	1.176	(.054)	1.034	(.044)	1.039	(.033)	1.179	1.068
1993Q2	1.104	(.041)	1.226	(.054)	1.111	(.043)	1.122	(.032)	1.236	1.096
1993Q3	1.093	(.045)	1.243	(.054)	1.122	(.043)	1.128	(.033)	1.236	1.096
1993Q4	1.055	(.042)	1.248	(.054)	1.112	(.043)	1.122	(.032)	1.257	1.116
1994Q1	1.180	(.044)	1.345	(.054)	1.214	(.043)	1.221	(.033)	1.381	1.159
1994Q2	1.167	(.041)	1.354	(.054)	1.216	(.042)	1.221	(.032)	1.404	1.193
1994Q3	1.139	(.041)	1.331	(.054)	1.187	(.043)	1.189	(.032)	1.371	1.201
1994Q4	1.129	(.041)	1.310	(.054)	1.169	(.042)	1.172	(.032)	1.351	1.192
1995Q1	1.156	(.043)	1.370	(.055)	1.219	(.043)	1.219	(.033)	1.389	1.206
1995Q2	1.304	(.041)	1.473	(.055)	1.336	(.042)	1.337	(.032)	1.491	1.270
1995Q3	1.321	(.040)	1.516	(.056)	1.373	(.042)	1.372	(.031)	1.544	1.347
1995Q4	1.366	(.041)	1.532	(.056)	1.396	(.043)	1.394	(.032)	1.567	1.359
1996Q1	1.444	(.041)	1.649	(.056)	1.503	(.042)	1.500	(.032)	1.703	1.428
1996Q2	1.520	(.040)	1.700	(.056)	1.561	(.042)	1.559	(.031)	1.777	1.500
1996Q3	1.475	(.040)	1.664	(.056)	1.523	(.042)	1.518	(.031)	1.747	1.513
1996Q4	1.500	(.040)	1.682	(.057)	1.542	(.042)	1.536	(.031)	1.768	1.528
1997Q1	1.566	(.040)	1.759	(.057)	1.617	(.042)	1.610	(.031)	1.826	1.567
1997Q2	1.665	(.040)	1.848	(.057)	1.711	(.042)	1.702	(.031)	1.909	1.610
1997Q3	1.659	(.039)	1.849	(.057)	1.711	(.042)	1.700	(.031)	1.917	1.664
1997Q4	1.714	(.040)	1.903	(.057)	1.763	(.042)	1.753	(.031)	1.957	1.701
1998Q1	1.773	(.039)	1.961	(.058)	1.825	(.042)	1.812	(.031)	2.017	1.752
1998Q2	1.794	(.039)	1.977	(.058)	1.842	(.042)	1.830	(.031)	2.036	1.774
1998Q3	1.811	(.039)	2.000	(.058)	1.865	(.042)	1.852	(.031)	2.066	1.798
1998Q4	1.780	(.039)	1.965	(.058)	1.832	(.042)	1.817	(.031)	2.032	1.796
1999Q1	1.819	(.039)	2.000	(.058)	1.871	(.042)	1.856	(.031)	2.063	1.821
1999Q2	1.789	(.039)	1.973	(.058)	1.845	(.042)	1.830	(.031)	2.061	1.817
1999Q3	1.834	(.039)	2.011	(.058)	1.889	(.042)	1.873	(.031)	2.113	1.851
1999Q4	1.870	(.039)	2.023	(.059)	1.909	(.042)	1.894	(.031)	2.132	1.873
2000Q1	1.853	(.039)	2.028	(.059)	1.912	(.042)	1.895	(.031)	2.143	1.883
2000Q2	1.860	(.039)	2.025	(.059)	1.909	(.042)	1.892	(.031)	2.133	1.885
2000Q3	1.834	(.039)	2.010	(.059)	1.894	(.042)	1.875	(.031)	2.125	1.892
2000Q4	1.832	(.039)	2.002	(.059)	1.887	(.043)	1.868	(.031)	2.123	1.896

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