WINE ANALYTICS:
FINE WINE PRICING AND SELECTION
UNDER
WEATHER AND MARKET UNCERTAINTY

M. HAKAN HEKIMOGLU, SYRACUSE UNIVERSITY
BURAK KAZAZ, SYRACUSE UNIVERSITY
SCOTT WEBSTER, ARIZONA STATE UNIVERSITY

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Southern Wine & Spirits of America is the nation’s largest wine and spirits distributor. The company began in Florida in 1968 and grew quickly through a strategy of acquiring other established distributors. Today Southern operates in 35 states and distributes over 5,000 brands.
Fine wine production

Sep 2014

May 2015

Wine futures of 2014 vintage

May 2016

Bottled wine of 2014 vintage
Bottles or Futures

- Sep 2014: Wine futures of 2014 vintage
- May 2015: Bottled wine of 2014 vintage
- Sep 2015: Wine futures of 2015 vintage
- May 2016: Bottled wine of 2015 vintage
Our (wine research) trail

Financial impact:
- Demonstrate with SW&S

Empirical analysis:
- Weather and market impact of futures and bottle prices

Mathematical model:
- Build on empirical findings and solve

Southern Wine & Spirits
Dedicated to Sales & Service

Bordeaux Wine Map
Digital Edition - Free to Share - Enjoy

Classifications of Bordeaux:
- Monopole Cru Classe
- Cru Bourgeois
- Côtes de Bordeaux

Most Popular Grape Varieties:
- Merlot
- Cabernet Sauvignon
- Cabernet Franc

290,000

Airline routes

USA

Map of Bordeaux wine regions
Weather impact

Wine futures of 2015 vintage

Bottled wine of 2014 vintage
Market impact

Wine futures of 2015 vintage
$$$ → $$$$$

Bottled wine of 2014 vintage
$$$ → $$$$$
Futures vs. Bottles (Analytical)

- Buy Futures (2015 Vintage)
- Buy Bottles (2014 Vintage)
- May'16
- Sep'16
- May'17

- Buy more
- or
- Sell some futures
- Buy more bottles
Empirical Analysis
## Liv-ex Data

**Winemaker**

<table>
<thead>
<tr>
<th>Angelus</th>
<th>Eglise Clinet</th>
<th>Lagrange St Julien</th>
<th>Pavie</th>
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<tr>
<td>Ausone</td>
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<td>Duhart Milon</td>
<td>Lafleur</td>
<td>Palmer</td>
<td>Vieux Château Certan</td>
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</tbody>
</table>

- **44 Bordeaux wineries** = 50 wineries that make up Liv-ex 500 index – 5 Sauternes – 1 missing data
- **Wine futures**: vintages from 2007 to 2011
- **Bottled wine**: vintages from 2006 to 2010
- **220 {winery, vintage} pairs for futures and bottles**
  - Total transactions = 43,837; Futures transactions = 10,451
  - Total bottle trades = 520,133
Functional forms of futures prices

Stage 1
May, Year \( t \)

Stage 2
September, Year \( t \)

Futures Price (Vintage \( t-1 \)):

\[
\frac{\partial f_2(\cdot)}{\partial w} < 0, \quad \frac{\partial f_2(\cdot)}{\partial m} > 0
\]

\[
\frac{\partial f_3(\cdot)}{\partial w} < 0, \quad \frac{\partial f_3(\cdot)}{\partial m} > 0
\]

Model 1A: \( (f_2^{j,t-1} - f_1^{j,t-1}) = \gamma_0 + \gamma_1 w + \gamma_2 m + \varepsilon_{j,t} \)

Model 1B: \( (f_3^{j,t-1} - f_2^{j,t-1}) = \eta_0 + \eta_1 w + \eta_2 m + \varepsilon_{j,t} \)

Parameter | Coefficient | \( t \)-stat
--- | --- | ---
Intercept | 0.0296 | 2.85***
w | -0.0501 | -4.58***
m | 0.0079 | 5.47***
R\(^2\) | 0.19 |
Observations | 220 |
Functional forms of bottle prices

Stage 1: May, Year $t$

Stage 2: September, Year $t$

Model 2A: $(b_2^{j,t-2} - b_1^{j,t-2}) = \theta_0 + \theta_1 w_t + \theta_2 m_t + \varepsilon_{j,t}$

Model 2B: $(b_3^{j,t-2} - b_2^{j,t-2}) = \lambda_0 + \lambda_1 w_t + \lambda_2 m_t + \varepsilon_{j,t}$

Parameter Coefficient $t$-stat Coefficient $t$-stat

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model 2A: $b_2^{j,t-2} - b_1^{j,t-2}$</th>
<th>Model 2B: $b_3^{j,t-2} - b_2^{j,t-2}$</th>
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<td>Intercept</td>
<td>0.0248</td>
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<td>$w_t$</td>
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<td>$m_t$</td>
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<td>$R^2$</td>
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<td>Observations</td>
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$w$ does not affect $b_2(m)$

$\partial b_3(\cdot)/\partial m > \partial b_2(\cdot)/\partial m > 0$
Analytical Model
Price evolution

Stage 1
May, Year $t$

Futures Price (Vintage $t - 1$):
$f_1 \rightarrow f_2(w, m) \rightarrow f_3(w, m)z_f$

Bottle Price (Vintage $t - 2$):
$b_1 \rightarrow b_2(m) \rightarrow b_3(m)z_b$

$f_1 = b_1 = 1$

Stage 2
September, Year $t$

Stage 3
May, Year $t + 1$
Notation

- $\phi_w(w)$, $\phi_m(m)$: pdf for weather and market r.v. on $[w_L, w_H]$ and $[m_L, m_H]$
- $\phi(z_f, z_b)$: pdf for stage-2 r.v. on $[z_{fL}, z_{fH}] \times [z_{bL}, z_{bH}]$
- $\beta$: tolerable loss
- $\alpha$: tolerated loss probability
- $B$: initial budget

Stage 1: Initial investment
- $x_1$: amount of futures of vintage $t - 1$
- $y_1$: amount of bottles of vintage $t - 2$

Stage 2: Adjusting allocation
- $x_2$: amount of futures of vintage $t - 1$ to buy or sell
- $y_2$: amount of bottles of vintage $t - 2$ to buy
Model infrastructure

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>May, Year t+1</th>
</tr>
</thead>
<tbody>
<tr>
<td>May, Year t</td>
<td>September, Year t</td>
<td></td>
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</table>

Decisions:
Buy futures (-$x_1$)
Buy bottles (-$y_1$)

Decisions:
Buy futures (-$f_2 x_2$)
or sell futures (+$f_2 x_2$)
Buy bottles (-$b_2 y_2$)

Constraints:
Budget
VaR
$x_2 \geq -x_1$

Revenues:
Bottled futures $(f_3(x_1+x_2))$
Bottles $(b_3(y_1+y_2))$

$$\Pi(x_1, y_1, w, m, x_2, y_2, z_f, z_b)$$
$$= -x_1 - y_1 - f_2(w, m)x_2 - b_2(m)y_2 + f_3(w, m, z_f)(x_1 + x_2) + b_3(m, z_b)(y_1 + y_2)$$
Analytical Model

Stage 2

\[
\max_{x_2, y_2} \mathbb{E}\left[ \Pi(x_1, y_1, w, m, x_2, y_2, \tilde{z}_f, \tilde{z}_b) \right]
\]

subject to

\[
f_2(w, m)x_2 + b_2(m)y_2 \leq B - x_1 - y_1 \quad \text{Budget constraint} \quad (2)
\]

\[
P\left[ \Pi(x_1, y_1, w, m, x_2, y_2, \tilde{z}_f, \tilde{z}_b) < -\beta \right] \leq \alpha \quad \text{Time-consistent VaR constraint} \quad (3)
\]

\[x_2 \geq -x_1 \quad (4)\]

\[y_2 \geq 0. \quad (5)\]

Stage 1

\[
\max_{x_1, y_1 \geq 0} \mathbb{E}\left[ \Pi(x_1, y_1, \tilde{w}, \tilde{m}, x_2^*(x_1, y_1, \tilde{w}, \tilde{m}), y_2^*(x_1, y_1, \tilde{w}, \tilde{m}, \tilde{z}_f, \tilde{z}_b)) \right]
\]

subject to

\[
x_1 + y_1 \leq B \quad \text{Budget constraint} \quad (7)
\]

\[
P\left[ \Pi(x_1, y_1, w, m, x_2^*(x_1, y_1, w, m), y_2^*(x_1, y_1, w, m, \tilde{z}_f, \tilde{z}_b)) < -\beta \right] \leq \alpha \text{ for all } (w, m) \in \Omega \quad (8)
\]

Stage 2 optimal policies

\[
(x_2^0, y_2^0) = \begin{cases} 
(-x_1, 0) & \text{if } (w, m) \in \Omega 1 \\
((B - x_1 - y_1) / f_2(w, m), 0) & \text{if } (w, m) \in \Omega 2 \\
(-x_1, (B - x_1 - y_1 + f_2(w, m)x_1) / b_2(m)) & \text{if } (w, m) \in \Omega 3
\end{cases}
\]

When \( E[f_3(\tilde{w}, \tilde{m}, \tilde{z}_f)] = E[b_3(\tilde{m}, \tilde{z}_b)] > 1 \)
Always invest in futures

\[ x_1^+ = \beta'[1 - f_2(w_H, m_L)] \]
\[ x_1^V = \left[ \beta + z_{\alpha} B \right] / \left[ (1 - f_2(w_H, m_T)) [1 + z_{\alpha}] \right] \]
\[ x_1^s = (\beta - B [1 - b_3(m_L) - z_{\alpha}]) / [b_3(m_L) + z_{\alpha} - f_2(w_H, m_L)] \]

**Proposition.** When (C1) holds and \((\tilde{z}_f, \tilde{z}_b)\) follow a bivariate normal distribution,

(a) If \( \{x_1^+, x_1^V\} \geq B \), then \((x_1^*, y_1^*) = (B, 0)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\);

(b) If \( x_1^V < B \leq x_1^+ \), then \((x_1^*, y_1^*) = (x_1^V, B - x_1^V)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\);

(c) If \( x_1^+ < \{x_1^V, B\} \), then
   
   (i) if (C2) holds, then \((x_1^*, y_1^*) = (x_1^V, 0)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\);
   
   (ii) if (C2) does not hold, then \((x_1^*, y_1^*) = (x_1^V, y_1^V)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\);

(d) If \( x_1^s < x_1^V \leq x_1^+ < B \), then
   
   (i) if (C2) holds, then \((x_1^*, y_1^*) = (x_1^V, y_1^V)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\);
   
   (ii) if (C2) does not hold, then \((x_1^*, y_1^*) = (x_1^V, y_1^V)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\);

(e) If \( x_1^V \leq x_1^s < x_1^+ < B \), then \((x_1^*, y_1^*) = (x_1^V, B - x_1^V)\) and \((x_2^*, y_2^*) = (x_2^0, y_2^0)\).
Financial Benefits
Southern Wine & Spirits of America is the nation’s largest wine and spirits distributor. The company began in Florida in 1968 and grew quickly through a strategy of acquiring other established distributors. Today Southern operates in 35 states and distributes over 5,000 brands.
### Financial Benefit:

$$\Delta = \frac{E[\Pi_1(x_1^*, y_1^*)] - E[\Pi_1(0, y_1^{**})]}{E[\Pi_1(0, y_1^{**})]}$$

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<tr>
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<th>Risk Neutral</th>
<th>Low Risk Aversion</th>
<th>High Risk Aversion</th>
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<tbody>
<tr>
<td>Angelus</td>
<td>11.47%</td>
<td>17.23%</td>
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<td>Ausone</td>
<td>39.12%</td>
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<td>0.98%</td>
<td>4.20%</td>
<td>9.84%</td>
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<td>6.01%</td>
<td>12.72%</td>
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<td>Carruades de Lafite</td>
<td>33.40%</td>
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<td>45.72%</td>
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<td>Cheval Blanc</td>
<td>24.05%</td>
<td>28.83%</td>
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<td>Clos Fourtet</td>
<td>13.92%</td>
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Average          | 22.78%       | 28.69%            | 34.46%             |

Relax Expected return[futures] = Expected return[bottles] assumption

$$B = 10000, \beta = 2000$$

Low risk aversion: $$\alpha = 0.20$$

High risk aversion: $$\alpha = 0.10$$
Conclusions and Managerial Insights

- Evolution of futures and bottled wine prices
- Warmer growing season for upcoming vintage negatively influences futures price but does not influence bottle price
- Improving market conditions has positive impact on both prices

- Build an analytical model based on an empirical foundation
- Futures are more profitable b/c of liquidity and swapping
- Despite being risky, always invest some in futures

- Financial benefit from our model ≈ 23%
- Risk-averse distributors benefit more from our model
- Futures market: not only beneficial for winemakers but also for distributors