Vines Portfolio Under Uncertainty and Irreversibility: Grapes Variety in a Real Option Approach

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Motivation

In Italy and Portugal wine-producers in the last 10-15 years have been facing critical long-term decisions:

- either keeping on growing local indigenous varieties of grape
- or introducing global, international varieties of grape

- In Sicily many have converted their vineyards from Catarraratto, Frappato, Inzolia, to Syrah, Cabernet Sauvignon, Chardonnay
- In Lazio some have started to grow Syrah, Merlot and Petit Verdot instead of indigenous Nero Buono, Pecorino, Bellone
- In Friuli, many have moved to Sauvignon from Ribolla Gialla and Tocai Friulano
- In Portugal, in Terras do Sado, some are growing Cabernet Sauvignon and Chardonnay instead of indigenous Touriga Nacional and Fernao Pires

What data show is that, in general, the number of wine produced by international grapes has been increasing over time in the last 15 years:

- not only because of the wine produced by the new world countries which exclusively use international grapes,
- but also for the higher share of international grapes in the old world countries:
  - in period 1995-2006 in Italy hectares with international grapes has increased of +13,6% (ISMEA);
  - in Portugal of +16,2% (IVV)

The hectares devoted to local indigenous grapes in Italy and Portugal have correspondingly shrunk….

to the point that many wine experts are now seriously concerned about the risks of losing the heritage of local indigenous grapes, with their peculiar characteristics in terms of aromas/tastes

What if all producers decide to switch to the international grapes?

Oenologists use to make a difference among:

- indigenous varieties of grape ("autochthonous"): had origin in Italy/Portugal, grown from centuries: Nebbiolo, Corvina, Sangiovese etc in Italy, Trincadeira Preta, Touriga Nacional, Arinto in Portugal.
- international varieties of grapes ("allochthonous"): introduced from foreign countries relatively recently (last 20 years or in XX century anyway) in order to produce wines with an explicit international appeal: mostly Cabernet Sauvignon (from Bordeaux) or Pinot Noir and Chardonnay (from Bourgogne).
- traditional varieties of grape: varieties of grape introduced from foreign countries a very long time ago (XI century) so that they evolved from the original ones and are now considered characteristic of the region:
  - examples in Italy are Cannonau (Grenache) or Vermentino in Sardegna, Pinot Noir in Sud Tirol;
  - in Portugal, Moscatel in Douro/Setubal (Muscat à Petit Grains, Muscat of Alexandria)
In Italy there are estimated 1532 indigenous varieties of grape,
In Portugal, 341, richest country in terms of number of grape varieties for vineyard hectares

Are the indigenous grapes seriously at risk?

- Obvious implications for the conservation of bio-diversity and natural species
- And also for the conservation of heritage of different local tastes and aromas as opposed to the global uniformity of tastes/aromas (a praise for Luigi Veronelli)
- But also for oenological interests: indigenous grapes can be the outcome of natural evolution and adaptation to local climate conditions, having developed resistance to pests and diseases!

Fortunately, the trend of replacing indigenous varieties with international ones is not in one direction only!

There are already many cases in which wine-producers go back to re-discover and to grow again indigenous varieties of grape:

- In Mazzorbo, a small island of Venice, a historical producer of Prosecco is going to re-implant and to grow an age-old white grape, Dorona, used to produce a wine for the Dogi in the XV century.
- In Lazio, some producers have now re-started producing wines from Cesanese and Passerina grapes.
- In Sicily, some small producers are bringing back wines from Caricante, Grencanico and Grillo grapes.
- In Portugal, some experiments have been done in Estremadura on old grapes like Alfrocheiro and Baga

Moreover, in Italy and Portugal many producers now try to make wines outside the DOC system by using fine mixtures of the indigenous grapes and the international grapes and results are extremely encouraging!

Thus, actual strategies for a wine-maker can be questions like:

- It is better to keep the indigenous grape from the region or to convert the vineyard to grow an international grape?
- It is better to specialize the production in a single grapevine, either indigenous or international, or to grow a mixed vineyard with different grapes?
- What is the optimal portfolio of grapes?

From an economist's point of view, a wine-maker's goal should be to optimize production and maximize returns.

However, wine-production faces many constraints of different nature:

- Oenological: different grapes may need different growing and production processes
- Weather/Climate: different grapes can fit and react differently to small changes in weather, or to radical change in climate conditions
- Resistance: different grapes can be more or less resistant to pests, diseases, bacteria and fungi
- Market: consumers can prefer the tastes and aroma of one grape to another’s

While first constraint is well-known and producers can easily deal with it, other 3 constraints are generally difficult to estimate ex-ante

Actually, costs/revenues implied by the last 3 constraints can be seen as stochastic
Therefore, from an economist’s perspective, a wine-producer should maximize her expected returns given the above, stochastic, constraints.

We propose a very simple benchmark model to study the optimal portfolio of grapes for a producer.

The irreversibility of growing/extirpating, the importance of timing and the stochastic environment all call for adopting a real option approach.

The final goal is the one to bring the model to the data:

looking at producers oenological choices of grapes and their vineyards’ extensions in the last 15 years in 2 North Italy wine-producing areas, Franciacorta and Veneto (still work in progress)

The Model

A (Portuguese/Italian) wine-producer has a limited extent of land, normalized to \( I \) that can be used as vineyard.

Wine-producer can use 2 grape varieties:

- an indigenous or "local" grape (\( LOC \))
- or an international one (\( INT \))

She decides the proportion of the vineyard in which to grow \( INT \) and \( LOC \) grapes, in order to grow either a single-vine or a mixed-vines vineyard.

A second interpretation is possible. Same problem under a different perspective: wine-producer has an equivalent harvest of both \( INT \) and \( LOC \) grapes and decides proportion in which to mix them, to produce either a varietal or a blended wine.

We will adopt first interpretation: implicitly assumed that switching from a grapevine to another is relatively quick. However, explicit delay/switching costs in can be introduced (at the cost of even more cumbersome expressions) and do not alter the main conclusions.

The indigenous \( LOC \) grape has always been grown locally and its transformation costs are very well-known; \( LOC \) is less vulnerable to pests/diseases.

- We assume its costs are constant over time and standardize them to 0.
- The \( LOC \) grape meet the tastes of consumers from the local market; wine made from \( LOC \) grape can be sold for a relatively low price \( q \) to a segmented market and therefore guarantees low revenues to the producer.

The international \( INT \) grape can meet the tastes of a larger international market:

- wine from \( INT \) grape can be sold for a relatively higher price \( p \) to a larger market and therefore guarantees higher revenues to the producer; i.e. \( p > q \)
- However, the international grape is newer for the producer and its growing and transformation costs are unknown and hardly predictable.

We assume these costs are stochastic and evolve over time: \( c_t \)

2 sources of uncertainty characterize the stochastic level of costs \( c_t \):

1. variations due to marginal changes on oenological or weather conditions: random fluctuations around a trend,
2. variations due to drastic changes in climate conditions or to the occurrence of pests or diseases: jumps driven by a Poisson process.

Costs follow a Geometric Brownian Motion (GBM) with Poisson jumps:

\[
\begin{align*}
dc_t & = ac_t + \sigma c_t dz_t + c_t dw_t, \\
ac_t & = \text{drift, either positive or negative, capturing either increasing or decreasing trend in costs of INT. Hp: } a \leq r, \text{ with } r \text{ the discount rate} \\
\sigma c_t dz_t & : \text{short term marginal variations around the trend; in particular:} \\
& \circ dz_t : \text{increment of a Wiener process such that } E[dz_t] = 0, \ E[dz_t^2] = dt \\
& \circ \sigma : \text{standard deviation} \\
c_t dw_t & : \text{long term radical variations, and in particular:} \\
& \circ \text{"jumps" in the costs due to pests or diseases according to a Poisson process for which at any instant of time} \\
dw_t & = \begin{cases} 
\theta & \text{with probability } \lambda dt \\
0 & \text{with probability } 1 - \lambda dt 
\end{cases}
\end{align*}
\]

If the pest/disease occurs, costs jump "up" of an extent \( \theta \), otherwise nothing happens and costs follow above the standard GBM.
In particular, if
\[ q - p - c_1 > 0 \]
\[ p - q > c_i \]
the wedge between two prices may cover the costs and make INT more profitable

If \( \gamma \leq 1 \), the wine-producer can adjust her production to changes in the costs of INT grape and can adopt a more flexible strategy for which

she can switch from a regime of exclusive INT grape to one with a mixed vineyard, MIX, encompassing some share of the indigenous grape (up to 1 at the extreme).

The above expressions describe the economic values of the vineyard at any instant. Now, the following condition must hold:

\[
\lim_{\gamma \to 1} \left[ V^{INT}(c_i;\gamma) - \left( \frac{p - c_1}{r - (a + \lambda \theta)} \right) ! \right] = 0
\]

when costs go to zero, INT grape gets "local", and being more profitable in terms of higher prices, the option to switch from a regime to another has zero value... so that the value of the vineyard is equal to the returns from growing the international grape forever.

On the other hand, when costs increase

\[
\lim_{\gamma \to 1} \left[ V^{MIX}(c_i;\gamma) - \left( \frac{p + (1 - \gamma)q - \gamma c_i - p + c_i}{r - (a + \lambda \theta)} \right) ! \right] = 0
\]

the option to switch from a mixed vineyard to a vineyard entirely with international grape has zero value and the wine-producer should never exert it since \( p - q < c_i \). The value of wine-production is the one from keeping forever the mixed vineyard as it is. Notice that costs are always discounted at a rate adjusted with the variations that affect them: \( r - (a + \lambda \theta) \).

From these two conditions, the value of the vineyard in the region \( p - q > c_i \) is

\[
V^{INT}(c_i;\gamma) = \frac{p}{r} - \frac{c_i}{r - (a + \lambda \theta)} + \lambda e^{\theta}
\]
The wine-producer should grow the international grape in all her vineyard, but should keep the option to switch to a mixed vineyard in case costs will increase. The value of such an option is $A_c^{\hat{\beta}_1}$, to be evaluated later on. On the other hand, the value of the vineyard in the region $p - q < c_i$ is

$$V^{\text{INT}}(c_i; \gamma) = \frac{yp + \gamma(1 - \gamma)y}{r - (a + \lambda)} - \frac{\gamma c_i}{r - (a + \lambda)} + B_c^{\hat{\beta}_2}$$

The wine-producers grows a mixed vineyard, but keeps the option $B_c^{\hat{\beta}_2}$ to switch to a vineyard exclusively grown with the international grape. The values $\hat{\beta}_1 > 1$, $\hat{\beta}_2 < 0$ can be found by solving numerically the expression

$$\frac{1}{2} \sigma^2 \beta (\beta - 1) + a \beta - (r + \lambda) + \lambda (1 + \theta) = 0$$

Putting everything together, the value of a vineyard is

$$V(c_i; \gamma) = \begin{cases} V^{\text{INT}}(c_i; \gamma) & \text{for } p - q > c_i \\ V^{\text{MIX}}(c_i; \gamma) & \text{for } p - q < c_i \end{cases}$$

$$A = (1 - \gamma)A = (1 - \gamma) \frac{(p - q)^{1 + \hat{\beta}_1}}{r - (a + \lambda)} \left(1 - \frac{a + \lambda}{\beta} \hat{\beta}_2 \right) \geq 0$$

$$B = (1 - \gamma)B = (1 - \gamma) \frac{(p - q)^{1 + \hat{\beta}_1}}{r - (a + \lambda)} \left(1 - \frac{a + \lambda}{\beta} \hat{\beta}_1 \right) \geq 0$$

$A_c^{\hat{\beta}_1}$, $B_c^{\hat{\beta}_2}$ are the values of the options to switch from INT to MIX regime and viceversa.

The values of both options are strictly positive for $\gamma < 1$. The values of options $A$ and $B$ can be computed by putting $c_i = p - q$ so that the two bits of the value functions equal, and have the same derivative in that point:

$$\begin{cases} V^{\text{INT}}(p - q; \gamma) = V^{\text{MIX}}(p - q; \gamma) \\ V^{\text{INT}}(p - q; \gamma) = V^{\text{MIX}}(p - q; \gamma) \end{cases}$$

Solving the system in the two unknowns and rearranging

$$\begin{cases} A(p - q)^{\hat{\beta}_1} = \frac{(1 - \gamma)(a + \lambda)}{r - (a + \lambda)} (p - q) + B(p - q)^{\hat{\beta}_2} \\ \hat{A} \beta_1(p - q)^{\hat{\beta}_1} = \frac{(1 - \gamma)}{r - (a + \lambda)} (p - q) + B \hat{\beta}_2(p - q)^{\hat{\beta}_2} \end{cases}$$

gives

$$\hat{A} = (1 - \gamma)A = (1 - \gamma) \frac{(p - q)^{1 + \hat{\beta}_1}}{r - (a + \lambda)} \left(1 - \frac{a + \lambda}{\beta} \hat{\beta}_2 \right) \geq 0$$

$$\hat{B} = (1 - \gamma)B = (1 - \gamma) \frac{(p - q)^{1 + \hat{\beta}_1}}{r - (a + \lambda)} \left(1 - \frac{a + \lambda}{\beta} \hat{\beta}_1 \right) \geq 0$$

Optimal choice of $I$-7

Now, the problem of a wine-producer can be of the following type. Assume the existence of a costly technology/insurance allowing the wine-producer to switch from a vineyard exclusively grown with INT grape to a MIX vineyard. Which share of the LOC grape $I - \gamma$ would be optimal? Assume the initial investment in such a flexible technology is sunk:

$$R(\gamma) = F + \hat{K}(1 - \gamma)^a$$

with $a > 1$

Notice that if $\gamma = 1$, the wine-producer spends only $F$ to grow the vineyard exclusively with INT grape, but she can in no way switch from the INT regime.

If, on the other hand, she wants to keep the option to switch back to the LOC grape, she needs to spend more than $F$, according to the second term. In particular, the greater is the extension she wants to switch back to the indigenous grape, the more she needs to spend in the costs of
technology/insurance.
Now, the question is: does such a technology exist?
Here we claim that a contribution to "leave the door opened" to LOC grape varieties can come from some form of co-operative mutual insurance by wine-producers or by public agronomic institutes.
Even in regions where they have switched to vineyards exclusively grown with INT grapes, wine-producers can have interests in keeping growing the LOC grape varieties on some common vineyard, from where they can eventually bring them back on their own vineyards.
The more extensively a wine-producer is willing to use this flexibility, the more she invests in the conservation of the LOC grapes in the common vineyard.
Such form of insurance can be equivalently arranged by means of mutual agreements by wine-producers, co-operative cellars, regional wines' consortia, public institute of agronomics etc.
Introducing such technology/insurance can help the conservation of the local indigenous grapes.

The optimal share of LOC grape is:
$$1 - \gamma^* = \begin{cases} (\frac{d\gamma}{K})^{\frac{1}{\beta}} & \text{if } c_i < \tilde{c} \\ 1 & \text{if } c_i \geq \tilde{c} \end{cases}$$
where 
$$\tilde{c} = \left( \frac{\Delta}{K} \right)^{\frac{1}{\beta}}$$

For low values of $c_i$, the wine-producer invests into the conservation vineyard to eventually switch back to the indigenous grape for a vineyard's extension strictly smaller than 1.
In the limit case, when $c_i = 0$, switching to the indigenous grape is a zero-value option, and therefore $1 - \gamma^* = 0$.
When $c_i$ gets higher, investing more extensively in the conservation insurance becomes more and more convenient. The higher is the cost, the less likely is that in the future the costs will meet the absorbing zero value and the more likely is that it will increase. Thus, insuring against such a risk may pay off.
$	ilde{c}$ is the threshold level differentiating the investment magnitude.
Conclusions

- A simple model to analyse the *optimal choice* of a wine-producer deciding
  - whether to grow an *indigenous* “local” or an *international* grape
  - having different profiles in terms of costs and final markets
- Results show that *growing a vineyard exclusively with an international grape may be a myopic strategy when costs are stochastic*
- And that *there is scope to grow mixed vineyards*, encompassing some shares of the indigenous “local” grapes.
- Results provide a *theoretical value to bio-diversity conservation as an option for flexibility*.
- We discuss the rationale for *common vineyards as mutual insurance against pests, diseases and climate changes*.
- A role for *wine-producing consortia, co-operatives or agronomics institutes* to guarantee grape bio-diversity and local heritage of tastes and aromas.
- *Benchmark model* can now be enriched and modified.
- We are now trying to *bring it to the data*, looking on *vineyards extensions* in North Italy regions in presence of different wine-producers’ organization.