

Decision making under uncertainty in viticulture: a case study of Port wine

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Abstract

In decision making under uncertainty individual decision makers (winegrowers) must choose one of a set number of decision alternatives with ample information about their outcomes but, most of the times, have not enough knowledge or data about the probabilities of the several states of nature. This paper focuses on the classical Maximax, Maximin, Minimax Regret and Realism criteria. The different approaches are analyzed and compared in a case study of Port wine production and selling. The computational involvedness and efficacy of the criterion are also presented. The paper finishes with the results of all observed criteria and alternatives in the circumstances of uncertainty.

Keywords: decision making under uncertainty, maximax, maximin, minimax and realism Criterion, Port Wine.

JEL Classification: D81, D70, C44, M10.

1. Introduction

Usually, individual and professional decisions are made with difficulty. In an uncertainty decision environment, the decision maker has no knowledge about the several states, not even enough knowledge to permit the assignment of probabilities to the states of nature. Decisions emerge where the course is not clear enough and it is necessary to take a lot of time and effort in developing a systematic method of analyzing the several alternative courses of action.

The uncertainty is particularly expressed in viticulture. Of all the Portuguese wines, Port wine is the most successful both in Portugal and abroad. For most choices in viticulture, uncertainty with regard to climacteric conditions, soil, economic resources, worldwide distribution, market behavior, evolution of sales and marketing, and cost of production decisions occurs.

Harris (1998) said “Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on.”

This research started at the *Instituto dos Vinhos do Douro e Porto* (IVDP) (www.ivdp.pt) which has its headquarters in Peso da Régua and in Porto. Some of the largest companies producing and exporting port wine with headquarters in Vila Nova de Gaia, opposite the old city centre of Oporto, were contacted.

Martins (1998) states that wine growing always had an important role in Portuguese agriculture, as wine plays a major role in the national economy. Wine production is an ancient tradition and has always been a priority of the Portuguese State for the development of the national economy.

2. Background of Port wine

The name of the wine descends from the name of the city, which in English descends from 'the port' in Portuguese (o Porto), but in Portuguese is simply 'Porto'. In common usage, the wine is called only 'port'.

According to Loureiro and Fernandes (2011) "Port wine is a fortified wine produced in the demarcated region of Douro. This region is situated in the northeast of Portugal, in the Douro hydrographical basin, surrounded by mountains that give it exclusive mesologic, climacteric and agrologic characteristics that enable the production of quality wines. Port wine is the most successful of all Portuguese wines throughout the years, home and abroad."

Fortified wines are made by adding a quantity of grape spirit, or brandy, to the wine at some point during the production process. The addition of the brandy takes place before the wine has finished fermenting. This means that the wine retains some of the natural sweetness of the grape, making it rich, round and smooth on the palate. One of the interesting aspects of Port wine is its variety of different styles, each with its own characteristic flavours. Usually it is served just before the end of the meal with cheese, as a dessert wine or as an after dinner drink although some styles, like white Port, can also be enjoyed as an aperitif. Port is considered as one of the most civilized and sociable of wines which will help to make any occasion special, whether a quiet evening by the fireplace, an informal meeting of friends or a sophisticated formal meal.

The grapes, mainly of native varieties such as the Touriga Nacional, Touriga Francesa, Tinta Roriz, Tinto Cão or Tinta Barroca, are grown on the steep rocky hillsides bordering the Douro River. Many of the oldest vineyards, now classified as World Heritage, are planted on narrow terraces supported by hundreds of hand built dry stone walls.

According to Carrera (1999), the colour of the different types of red Port Wine may vary from deep purple to light gold, and all intermediary hues can occur (red, tawny, golden and light gold). White Port wines can also come in diverse shades (pale yellow, straw and golden white), all intimately related to the winemaking technique used. When white wines are aged in cask they acquire a golden hue very similar to that of very old red wines.

The process of ageing a Port Wine can be done in two different ways (www.ivdp.pt):

Ruby (bottled matured) - When the objective is to restrain the evolution of the red colour, more or less intense, and maintain the fruity flavour and vigour of young wines. This ageing process is applied to the following categories in ascending order of quality; Ruby, Reserve, *Late Bottled Vintage* and *Vintage*. The finest category wines, especially *Vintage* and to a lesser extent LBV can be bottled as they age quite well in bottle.

Tawny (wood ageing) - obtained from blending wines with different maturing degrees, aged in casks or bats. With age, the colour of the wines slowly develops into tawny, medium tawny or light tawny. The aromas remind you of dried fruits and wood, and these get stronger with age. The following categories fall in these styles: Tawny, Tawny Reserve, and Tawny with an indication of age (10 years, 20 years, 30 years and 40 years) and produce (*Colheita*).

Located in Northeast Portugal, within the Douro River basin, surrounded by craggy mountains that give it very particular soil and climacteric characteristics, this region spreads over a total area of approximately 250 000 hectares and is divided into three sub-regions (Lower Corgo, Upper Corgo and Upper Douro) that differ greatly from each other not only as regards the weather but also for socio-economical reasons.

Vines cover approximately 15.4% of all the land in the region. The land under vines is worked by approximately 39 000 farmers, each owning an average of 1 ha under vines. Small farmers are very representative in the production of Port Wine.

The most important single country foreign markets (Table No. 2) are France, Netherlands, Belgium, Portugal itself, and UK, collectively accounting for 78% of total sales (IVDP, 2013).

Table 1

Description of the Sub-Regions and Structure of the vineyards

Sub-Region	Total Area (ha)	Area Under Vines (ha)	Number of farmers	Area under Vines/farmers (ha)
Lower Corgo	45 000	14 582	15 493	0,94
Upper Corgo	95 000	20 969	16 270	1,29
Upper Douro	110 000	10 175	7 348	1,38
Total	250 000	45 726	39 111	1,17

Source: www.ivdp.pt (14/06/2013)

Table 2

PORT WINE TRADE JANUARY - APRIL 2013							
MAIN MARKETS	MARKETS	BOTTLED STANDARD PORTS (1)			BOTTLED PREMIUM PORTS (2)		
	%	9 l cases	euros	euros/litre	9 l cases	euros	euros/litre
7- GERMANY	4.8	102 618	3 119 895	3.38	12 725	893 344	7.80
21- AUSTRIA	0.2	3 657	143 934	4.37	798	98 367	13.70
3- BELGIUM	11.2	248 468	7 823 117	3.50	18 743	1 844 566	10.94
11- BRAZIL	1.1	23 689	822 077	3.86	3 572	311 738	9.70
8- CANADA	1.8	13 203	640 869	5.39	28 523	2 767 722	10.78
12- DENMARK	1.1	17 885	555 602	3.45	7 675	701 091	10.15
6- USA	4.9	57 962	2 183 252	4.19	58 535	5 146 277	9.77
9- SPAIN	1.5	33 632	1 162 456	3.84	2 471	215 238	9.68
23- FINLAND	0.1	1 420	64 402	5.04	2 125	186 524	9.75
1- FRANCE	33.2	710 758	20 590 677	3.22	59 481	4 082 053	7.63
2- HOLLAND	16.5	362 949	10 325 724	3.16	30 303	2 317 785	8.50
22- IRELAND	0.2	3 657	192 649	5.85	727	44 161	6.75
14- ITALY	0.8	17 278	643 569	4.14	859	92 342	11.95
18- JAPAN	0.3	5 746	362 505	7.01	436	44 313	11.30
16- LUXEMBOURG	0.4	7 621	277 528	4.05	935	85 972	10.22
19- MEXICO	0.2	5 111	193 309	4.20	549	101 776	20.59
20- NORWAY	0.2	1 147	58 103	5.63	4 108	274 952	7.44
25- NEW ZEALAND	0.1	834	40 281	5.37	1 352	77 929	6.40
10- POLAND	1.2	24 543	631 753	2.86	3 942	188 748	5.32
4- PORTUGAL	10.5	215 639	7 123 717	3.67	34 942	3 790 491	12.05
5- UNITED KINGDOM	6.3	100 433	2 889 816	3.20	49 372	3 063 779	6.89
24- CZECH REPUBLIC	0.1	2 381	86 943	4.06	515	56 051	12.09
17- RUSSIA	0.3	5 062	178 676	3.92	1 640	237 185	16.07
15- SWEDEN	0.4	6 621	258 056	4.33	2 095	170 321	9.03
13- SWITZERLAND	0.8	16 456	666 253	4.50	1 946	278 479	15.90
OTHERS	1.8	27 421	1 110 323	4.50	15 755	3 690 446	26.03
TOTAL	100.0	2 016 190	62 145 486	3.42	344 123	30 761 650	9.93

Source: www.ivdp.pt (14/06/2013)

Note: (1) Includes Ruby, Tawny and White Port; (2) Includes Vintage and LBV

3. Elements of a decision-analysis problem

In a decision making process under uncertainty we can consider the four basic features of a decision-making situation.

- Decision Alternatives or Actions or Alternative Courses of Action are the number of choices or options available to the decision maker in any given problem situation.
- States of Nature or Events are the occurrences of nature that can happen after a decision is made that can affect the outcome of the decision and over which the decision maker has no control.
- The Payoffs are the benefits or rewards that result from selecting a particular decision alternative. In the financial investment industry, for instance, the payoffs can be small, modest, or big, or the investment can result in a loss.
- Decision criteria need to be well known because they will help the decision maker to select the best course of action.

So, the first step a decision maker must take is to list all the possible alternatives that must be considered in the decision. After having identified all the possible alternatives, the decision maker must list the future events that may occur. In order to evaluate each course of

action, a decision maker must associate a value or payoff with the result of each event. Then discusses which decision criteria under uncertainty: maximax, maximin, minimax and realism criterion, that best fits with the decision maker objectives.

4. Methodology

Decision analysis employs a diversity of tools to estimate all important information to support in the decision making process. A model is developed to characterize the decision making problem, assist the progress of rational analysis, and originate a suggested course of action. This is a very convenient method in managerial situations where risk is significant. The subsequent model is able to create optimal strategies for multi-stage decision making problems that involve several possibilities. Therefore, the Decision Matrix properly defines a decision analysis problem.

The Decision Matrix is frequently used to provide the payoff for each combination of an action/decision maker's alternatives and an event/demand/states of nature.

Table No. 3 shows the structure of a decision matrix or payoff table. On the left side of the table are the different decision alternatives or actions, denoted by $a_i, i = 1, \dots, m$. Through the top row are the actions or states of nature, denoted by $\theta_j, j = 1, \dots, n$. In the middle of the table are the several payoffs for each decision alternative under each state of nature, denoted by $U_{ij}, i = 1, \dots, m, j = 1, \dots, n$.

Table 3

Decision Matrix or Payoff table $U_{ij} = U(a_i; \theta_j)$

Actions/Alternatives	Events/States of Nature				
	θ_1	θ_2	θ_3	$\dots$	θ_n
a_1	U_{11}	U_{12}	U_{13}	$\dots$	U_{1n}
a_2	U_{21}	U_{22}	U_{23}	$\dots$	U_{2n}
a_3	U_{31}	U_{32}	U_{33}	$\dots$	U_{3n}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
a_m	U_{m1}	U_{m2}	U_{m3}	$\dots$	U_{mn}

The discussion about criteria for decision making has emerged in the early 1950s. Some decision criteria have been proposed to solve the problem of decision making under uncertainty. The most important ones are furthermore presented.

4.1 Maximax Criterion

Is an optimistic criterion, the decision maker will select the decision alternative which will maximize the maximum payoff.

The decision maker first selects the maximum payoff possible for each decision alternative and then chooses the alternative that provides him with the maximum payoff within this group.

The action to be chosen should then be the one that:

$$\max_{a_i} \left\{ \max_{\theta_j} U(a_i; \theta_j) \right\}$$

4.2 Maximin Criterion

Is a pessimistic criterion, the decision maker will select the decision alternative which will maximize the minimum possible payoff.

The decision maker first selects the minimum payoff possible for each decision alternative and then chooses the alternative that provides him with the maximum payoff within this group.

The action to be chosen should then be the one that:

$$\max_{a_i} \left\{ \min_{\theta_j} U(a_i; \theta_j) \right\}$$

4.3 Minimax Regret Criterion (Savage)

This criterion gets away from the focus on optimism versus pessimism. Instead, its focus is on choosing a decision that minimizes the *regret* that can be felt afterward if the decision does not turn out well.

After decisions have been made and the events occurred, decision makers may express regret because they now know what event has taken place and may wish they had selected a different action. This criterion intends to minimize this regret.

To apply this criterion, the Decision Matrix must be transformed into a Regret Matrix, by using the following transformation

$$R(a_i; \theta_j) = \max_{a_k} \{U(a_k; \theta_j)\} - U(a_i; \theta_j)$$

and the Minimax criterion must be applied to the Regret Matrix

$$\min_{a_i} \left\{ \max_{\theta_j} R(a_i; \theta_j) \right\}.$$

4.4 Criterion of Realism (Hurwicz)

Is a middle ground criterion between maximax and maximin criterion, that is, between optimistic and pessimistic criterion. This criterion requires the decision maker to specify a coefficient of optimism, represented by α , where α is between 0 and 1 (0 express pessimism about nature, 1 express optimism about nature). First we must determine both the maximum and the minimum payoff for each decision alternative.

Then for each decision alternative, compute:

- Measure of realism = $\alpha(\text{maximum payoff}) + (1-\alpha)(\text{minimum payoff})$
- Choose the action alternative with the best Measure of realism as the chosen decision.

5. Results

Decision theory has, for cases under uncertainty, two main techniques. The first one is to transform the uncertainty case into a case of risk by using probabilities, constructed on expert assessments on analysis of earlier decisions made in analogous situations. The second technique exploits criteria of choice developed in a wide-ranging situation by game theory. In the article the second approach was presented and applied. For the analysis Maximax, Maximin, Minimax Regret and Realism criteria are computed and discussed in the sample of Port wine production and selling.

A small farm representative in the production of Port Wine has been in business for 22 years in Pinhão. The company was created by father and son who had worked in the Port wine production since ever. They saw an opportunity to get into the Port wine business and as they wanted to get their own business, they decided to buy some hectares of land and to hire people to work in their business. They found a dedicated workforce and soon employed 73 people. Business had been really good until two years ago, when profits began to decline a little, with the Portuguese economic crisis. The company analysed the situation and as their vineyards were planted according to the natural slope of the land, mechanization is now

impossible on these terraces as there are no or few access roads and the steeper vineyards are heavily planted. Because of this and the high costs of labour that this type of terraces implies, they realize their company must invest in mechanization on their land so they will need to construct a new type of terraces. These are horizontal terraces with earthen supporting walls, each bearing 1 or 2 rows of vines planted far enough apart for a small tractor to move between them and with a low planting density of 3 000 to 3 500 vines/ha.

Image 1

Douro Vineyard Terraces



But they were uncertain about the amount of investment needed. Initial research led them to identify three possible courses of action (alternatives):

A1: A large investment, which would involve purchasing more land and machines, given the need of large plots of land for this type of vineyard (as it is not suitable for smallholdings). This new alternative would give them greater capability.

A2: A medium investment, which would give them the same general capability as alternative A1, after changing some of their own terraces and purchasing some machines. But the equipment wouldn't operate as fast as in alternative A1. This would prevent them from bidding on large contracts.

A3: A small investment, which would limit them to bidding on less than half of the possible contracts.

Of course, the alternative they should select depends on the future profits generated by the new investment in land and equipment. Therefore, they identified three states of nature, potential directions that they believed the demand for Port wine could take.

For them, the states of nature were:

S1: Large increase in demand due to the capability of the new equipment

S2: Moderate increase in demand

S3: Small increase in demand

Because their decision involved three alternatives and three states of nature, they had nine possible payoffs to consider, as we can see in the Table No. 4.

Table 4

Payoff Table for Port Wine Company Expansion Decision

	Events/States of nature (demand)		
	S1 (Large increase)	S2 (Moderate increase)	S3 (Small increase)

Actions/ Decision maker's alternatives	A1 (Large investment)	500 560 €	350 034 €	- 200 123 €
	A2 (Medium investment)	300 437 €	400 354 €	- 150 937 €
	A3 (Small investment)	180 862 €	120 402 €	100 958 €

(Payoffs per year)

5.1 Maximax Criterion

As it is an optimistic criterion, the decision maker will select the decision alternative which will maximize the maximum payoff.

In Table No. 5, the maximum payoff possible for each of the three decision alternatives is in the last column.

Table 5

Results for Maximax Criterion

Actions/ Decision maker's alternatives	Events/States of nature (demand)				
		S1	S2	S3	$\max_{\theta_j} U(a_i; \theta_j)$
A1 (Large investment)		500 560 €	350 034 €	- 200 123 €	500 560 €
A2 (Medium investment)		300 437 €	400 354 €	- 150 937 €	400 354 €
A3 (Small investment)		180 862 €	120 402 €	100 958 €	180 862 €

The alternative within this group of three which provides the maximum payoff is “Large investment”, with an associated payoff of 500 560 € per year. This action corresponds to

$$500\,560 = \max_{a_i} \left\{ \max_{\theta_j} U(a_i; \theta_j) \right\}$$

If they are not optimistic, they might select the alternative whose worst possible outcome is better than the worst possible outcome from any other alternative.

5.2 Maximin Criterion

Is a pessimistic criterion, the decision maker will select the decision alternative which will maximize the minimum possible payoff.

In Table No. 6, the minimum payoff possible for each of the three decision alternatives is in column number six.

Table 6

Results for Maximin Criterion

Actions/ Decision maker's alternatives	Events/States of nature (demand)				
		S1	S2	S3	$\min_{\theta_j} U(a_i; \theta_j)$
A1 (Large investment)		500 560 €	350 034 €	- 200 123 €	- 200 123 €
A2 (Medium investment)		300 437 €	400 354 €	- 150 937 €	- 150 937 €
A3 (Small investment)		180 862 €	120 402 €	100 958 €	100 958 €

The alternative within this group of three which provides the maximum payoff is “Small investment”, with an associated payoff of 100 958 € per year. This action corresponds to

$$100\,958 = \max_{a_i} \left\{ \min_{\theta_j} U(a_i; \theta_j) \right\}$$

But maximax and maximin criteria have a disadvantage because they use only one value from the payoff matrix to make a decision. In evaluating the decision situation, the company owners can be interested in determining how much loss making the wrong choice would cause. Suppose they decided on the medium investment alternative and later found that the market for Port wine capability had a big expansion. The medium investment decision led to a 300 437 € yearly profit, but given perfect reflection, the best decision of making a large investment would have earned 500 560 €. The difference between the actual payoff and the optimal payoff for a given state of nature is an opportunity loss or regret resulting from their decision; in this case, it is 200 123 €. If they decided to use the minimax regret criterion, they would need to know the value of the opportunity loss.

5.3 Minimax Regret Criterion (Savage)

After decisions have been made and the events occurred, decision makers may express regret because they now know what event has taken place and may wish they had selected a different action. This criterion intends to minimize this regret.

In Table No. 7, we can see the regret values obtained by subtracting each entry in the payoff table (Table No. 4) from the largest entry in its column. The maximum regret for each of the three decision alternatives is in last column.

Table 7

Opportunity-Loss Table					
Actions/ Decision maker's alternatives	Events/States of nature (demand)				
		S1	S2	S3	$\max_{\theta_j} P(a_i; \theta_j)$
	A1 (Large investment)	0 €	50 320 €	301 081 €	301 081 €
	A2 (Medium investment)	200 123 €	0 €	251 895 €	251 895 €
	A3 (Small investment)	319 698 €	279 952 €	0 €	319 698 €

Finally they choose the minimum of these three regret values, in this case, 251 895 € is the minimum regret value, and it is associated with deciding to “Medium investment”. This action corresponds to:

$$251\,895 = \min_{a_i} \left\{ \max_{\theta_j} P(a_i; \theta_j) \right\}$$

5.4 Criterion of Realism

According to this criterion, the decision maker is between pessimistic and optimistic attitude. Each result has been weighted according to optimistic coefficient ($\alpha = 0.7$). The highest and the lowest values of each business alternative has been multiplied by optimistic coefficient ($k = 0.7$) and pessimistic coefficient ($1 - \alpha = 0.3$), as we can see in Table No. 8.

Table 8

Measures of Realism	
Large investment	$0.7 \times (500\,560) + 0.3 \times (-200\,123) = 290\,355.1 \text{ €}$

Medium investment	$0.7 \times (400\,354) + 0.3 \times (-150\,937) = 234\,966.7 \text{ €}$
Small investment	$0.7 \times (180\,862) + 0.3 \times (100\,958) = 156\,890.8 \text{ €}$

The use of the realism criterion in this case advises to choose the alternative “Large investment” (290 355.1 €).

Summarized Results of Recommended Alternatives of Port Wine Production and Sales

Criterion	Recommended Alternative
Maximax Criterion	Large investment
Maximin Criterion	Small investment
Minimax Regret Criterion	Medium investment
Criterion of Realism	Large investment

6. Conclusion

The maximax, maximin, minimax regret and realism criterion are examples of non-probabilistic decision criteria. In non-probabilistic criteria we do not take into account the probability associated with the outcomes for each alternative. Consequently decision makers have to choose, in the absence of any information about the probabilities of the several states of nature, one of supposed business alternatives.

Observe that the first three criteria lead to different decisions; therefore, the decision makers (winegrowers) would determine which criterion best described their decision making attitude and use it to help them decide on their level of investment.

In this article was presented a decision making process under uncertainty related with Port wine production and sales. The maximax, maximin, minimax regret and realism criterion were evaluated and compared in the case study. The results indicate that the alternative “Large investment” is the best decision to make. We are certain of that there is a need to give more importance on determining the uncertainty in viticulture, especially in Port wine production.

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