University of Illinois

# Freemark Abbey Winery

Decision Analysis Case Study

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# Executive Summary

## Introduction

The purpose of this study was to perform a decision analysis to recommend a course of action to the decision maker, Mr. Jaeger, owner of the Freemark Abbey Winery. This report summarizes the problem, assumptions, analysis and final recommendations. An attachment with the supporting analysis is included as a reference at the end of the report.

Mr. Jaeger is currently facing the decision of whether to harvest the Riesling grapes immediately or leave them on the vines despite the approaching storm. The decision has important consequences on the type of wine, which is dependent on the ripening process and balance between acidity and sugar concentration. It is also known the rain and mold formation affect this balance.

Based on his current state of information, Mr. Jaeger has provided his belief (i.e. probability assessment) of several relevant uncertainties: the storm, Botrytis mold formation, acidity and sugar level. He has also provided information about the prices of the type of wines resulting from the different outcomes. The aspects of his preferences are money and reputation of the Winery.

## Assumptions

Several assumptions were made in order to carry out the decision analysis. These decision model assumptions are as follows:

- Mr. Jaeger is a risk-neutral person
- The reputation impact per bottle is +$1.00 and -$1.50 for “superior” (i.e. Botrytis) and “inferior” (i.e. Thin) wine respectively; there is no impact on the other “standard” wines
- Net revenue only depends on the number of bottles, price per bottle, and reputation impact
- Cost difference of the different types of wine are negligible
- Outcomes are only based on the net revenue
- Number of cases = 1,000 (12 bottles per case)
- There is a 7.5% increase in wine volume due to the swelling of the grapes if the mold is not formatted after the storm.
- There is 30% decrease in wine volume due to the formation of the mold after the storm
- For acidity levels greater or equal than 0.7%, the concentration of sugar is either 20% or 25%
- For acidity levels less than 0.7%, the concentration of sugar is less than 19%
- For the sensitivity analysis on Mr. Jaeger’s risk attitude, the utility function has the from $U(x) = 1 - e^{-\gamma x}, \gamma = 0.01$ (risk-aversion assumed).

The first assumption is one of the most important one and is made because of lack of assessment of Mr. Jaeger’s risk attitude. The second assumption was made because Mr. Jaeger cares about the reputation of the Winery, but no information regarding the value of the reputation is provided. The values of the reputation were chosen based on a rough comparison between the prices of the different types of wine, and assuming the magnitude of the negative reputation is greater than that of the positive one. Because these two assumptions are very important, a sensitivity analysis on the risk tolerance and reputation values was done to test the model and increase the understanding of the decision problem.

## Analysis

Based on the description of the decision problem and model assumptions discussed, a decision tree (Figure 1) was constructed to capture the alternatives, uncertainties and outcomes. Rolling back the tree, the results show that the certain equivalent of the alternative "wait" is higher than that of "harvest now". Thus, the best decision is to wait for the harvest after the store. If there is a storm but the mold is not formed, the best decision is to sell the wine in bulk instead of bottle.

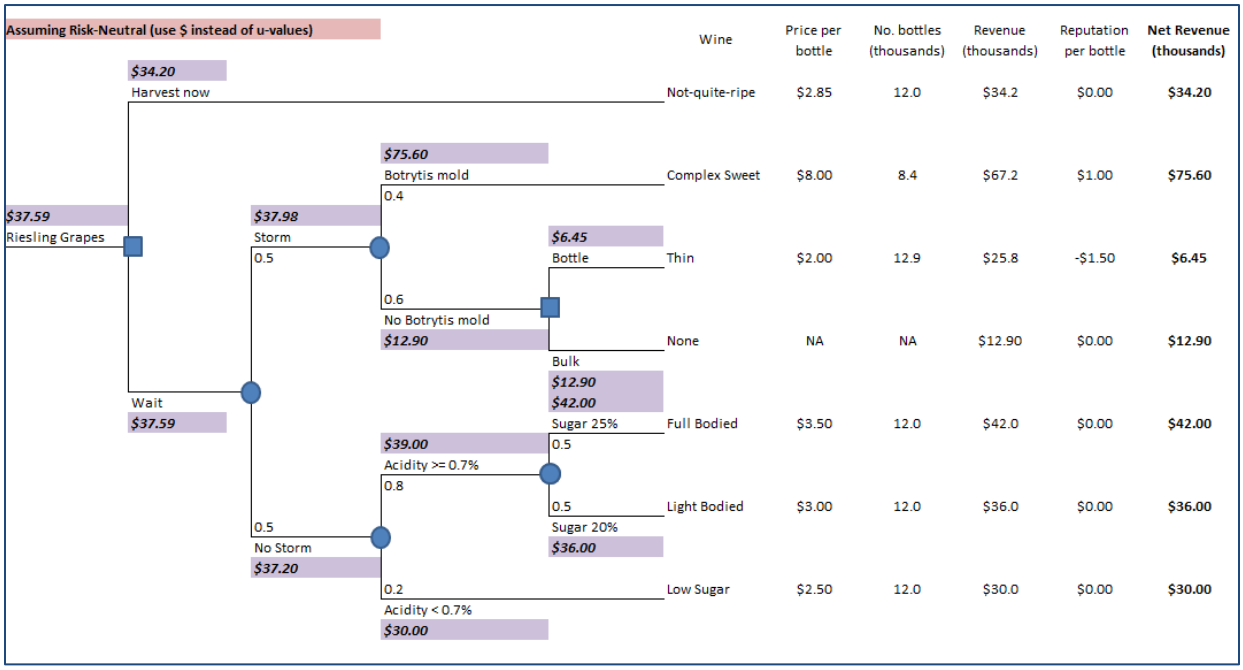



**Figure 1. Decision Tree (Risk-Neutral)**

A sensitivity analysis on different parameters was conducted to test the model assumptions, gain insights on the most critical parameters of the decision model, and understand how changes in problem inputs affect or alter the recommended alternative. The sensitivity analysis for all parameters (except risk tolerance) was conducted based on the decision model described above (Figure 1).

The summary of the sensitivity analysis is shown in Table 1. As it can be seen, when the parameter takes its original value, the decision is to "wait". The decision is insensitive to the inputs of probability of storm, the reputation values and swelling due to water over the specified range. Regarding the decision to bottle or bulk if there is a storm and no mold formation, the decision changes from bulk to bottle when the magnitude of the reputation value for inferior wine is less than $1.00 per bottle. The price of the not-quite-ripe wine (when harvest now) affects the decision, changing it from "wait" to "harvest now" when the price is over $3.13.

The sensitivity analysis shows also that the probability of botrytis, price of botrytis and risk tolerance seem to be important inputs as they affect the decision. The corresponding plots (Figure 2, Figure 3, Figure 4) show that the decision changes from "wait" to "harvest now" when the inputs of probability of botrytis, price of botrytis and risk tolerance drop below 0.292, $5.98 or $66 thousands respectively. In terms of percentage change, the decision will change if the values for these inputs decrease by 27%, 25% or 33% respectively.

| Parameter (Y) | Original (R) | Indifference point (Z) | Percent difference | If Yequal to R | If Y less than Z | If Y greater than Z |
|---|---|---|---|---|---|---|
| **P(Storm)** | 0.5 | None | NA | Wait | Wait | Wait |
| **P(Botrytis)** | 0.4 | 0.292 | -27% | Wait | Harvest Now | Wait |
| **Price of Botrytis** | $8.00 | $5.98 | -25% | Wait | Harvest Now | Wait |
| **Reputation per bottle for superior wine** | $1.00 | None | NA | Wait | Wait | Wait |
| **Reputation per bottle for inferior wine** | -$1.50 | None | NA | Wait | Wait | Wait |
| **Swelling due to water** | 7.50% | None | NA | Wait | Wait | Wait |
| **Price of Not-quite-ripe wine** | $2.85 | $3.13 | 10% | Wait | Wait | Harvest Now |
| **Risk Tolerance (thousands)** | $100 | $66 | -34% | Wait | Harvest Now | Wait |
| **Reputation for inferior wine (bottle/bulk)** | -$1.50 | -$1.00 | -33% | Bulk | Bulk | Bottle |

Table 1. Sensitivity Analysis Summary

The results for the risk tolerance make sense, since as the risk tolerance of Mr. Jaeger increases, the decision to wait (more uncertainty and risk) becomes better than harvest now. In addition, comparing the risk-neutral (Figure 1) and risk-averse (see attachment) model, the certainty equivalence for the former is greater than that of the latter, which makes sense since Mr. Jaeger would be less willing to take the riskier alternative in the risk-averse model. In other words, the difference in certainty equivalence between the alternatives in the risk-averse model is smaller than that of the neutral-risk model. For the probability of Botrytis, the value of perfect information was found to be $5.49 thousands, which provides an upper bound on any information gathering activity of the probability of the formation of the botrytis mold. The maximum value of this information occurs when the P(Botrytis) equals 0.292, which is the indifferent point between the two alternatives (see attachment for details).

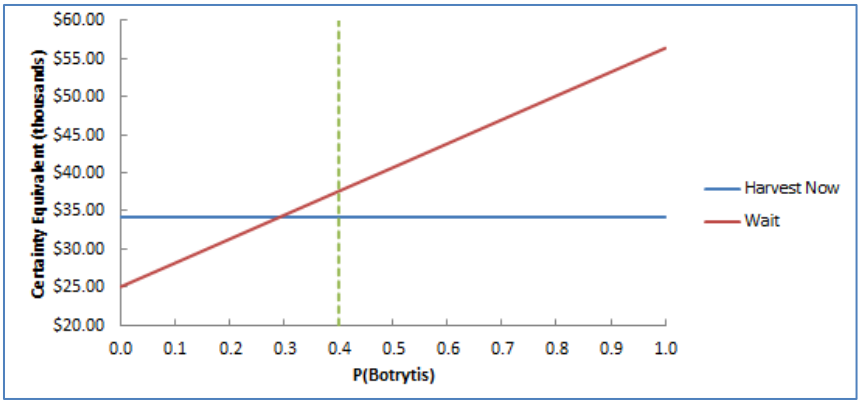



Figure 2. Sensitivity to P(Botrytis)

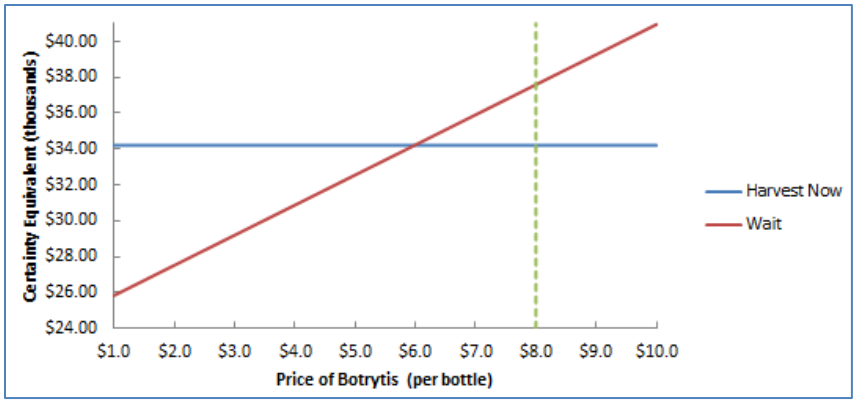



Figure 3. Sensitivity to Price of Botrytis

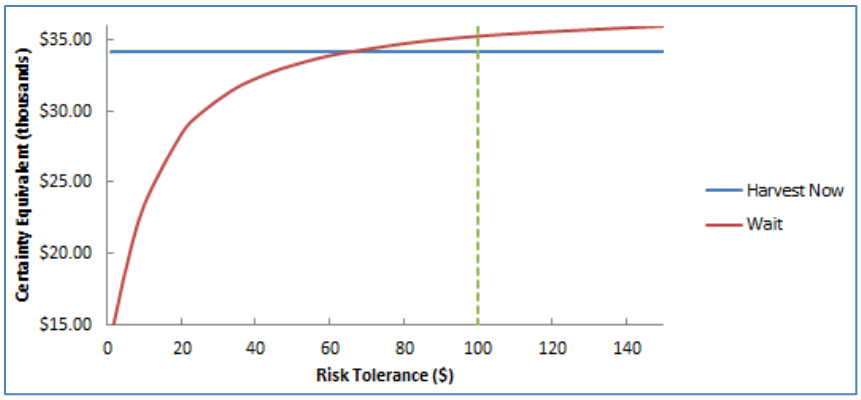



Figure 4. Sensitivity to Risk Tolerance

## Recommendations

Based on the information and assessment provided by Mr. Jaeger, the final recommended course of action is to wait and leave the Riesling grapes on the vines despite the approaching storm instead of harvest them immediately. If there is a storm but the mold is not formed, the best decision is to sell the wine in bulk instead of bottle.

The reasoning for selecting this recommendation is based on sensitivity analysis conducted. The analysis on the risk-averse model showed that the best alternative is to "wait", and this decision is insensitive to most inputs that were considered important. For the other critical inputs, the values would have to change significantly (25%-34%) to change the decision. In addition, even though Mr. Jaeger believes that botrytis, which is tied to the best outcome, is less likely to be formed (0.4), the analysis showed that he should take the riskier alternative and "wait". For the decision to change, his belief of the formation of botrytis would have to drop significantly by 27%. For the risk-averse model, the analysis also showed that the best alternative was to "wait".

If information can be gathered regarding the probability of botrytis, it is recommended not to spend more than $5.49 thousands. Furthermore, it is recommended to clarify the assumptions and assess the risk attitude of Mr. Jaeger to have a more accurate representation of the decision problem. Once this information is available, the attached spreadsheet model used for the decision analysis can be easily updated to determine the best alternative.

# Attachment

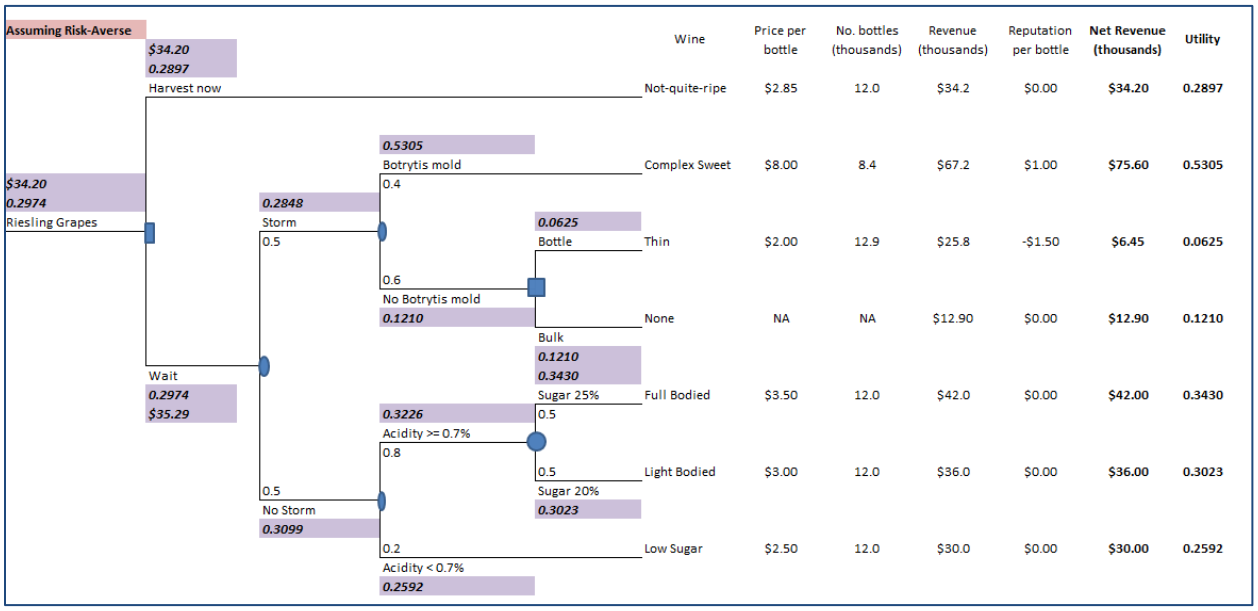
## Parameter Table

| Parameters | |
|---|---|
| **P(Storm)** | 0.5 |
| **P(Botrytis)** | 0.4 |
| **P(Acidity < 0.7%)** | 0.2 |
| **P(25% Sugar)** | 0.5 |
| **P(20% Sugar)** | 0.5 |
| **Swelling due to water** | 7.50% |
| **Reduction in juice** | 30% |
| **Reputation per bottle for superior wine** | $1.00 |
| **Reputation per bottle for inferior wine** | -$1.50 |
| **Gamma (Risk aversion coefficient) 1/$** | 0.0100 |

## Price Table

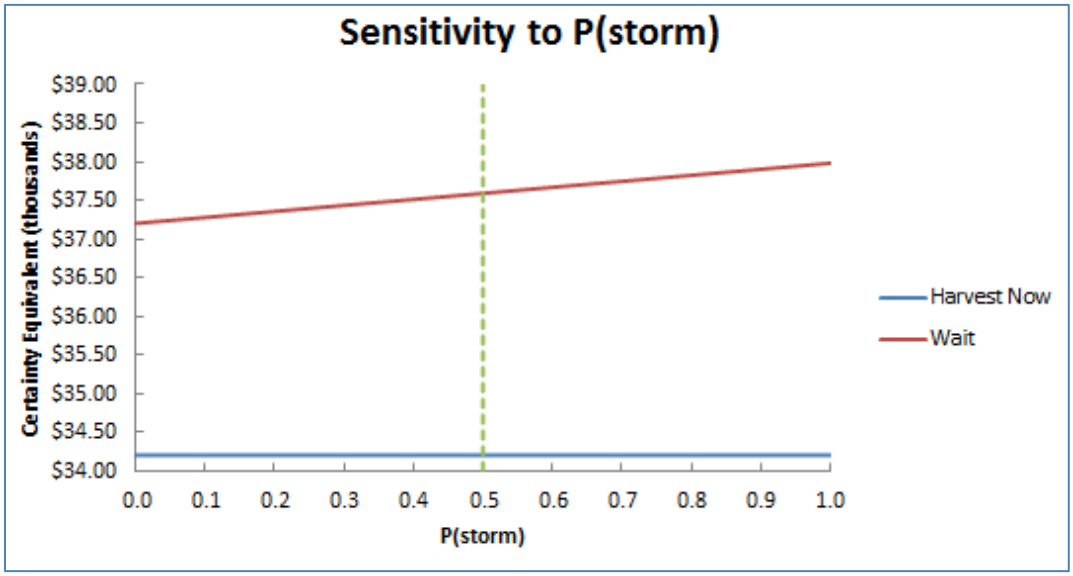
| Wine | Description | Price per bottle |
|---|---|---|
| **Botrytis** | Complex Sweet | $8.00 |
| **25% Sugar** | Sweet and full bodied | $3.50 |
| **20% Sugar** | Light bodied | $3.00 |
| **Not-quite-ripe** | Standard | $2.85 |
| **Acitidy < 0.7%** | Standard | $2.50 |
| **Thin** | Inferior | $2.00 |
| **Bulk/Direct grapes sell** | No bottle | NA |

## Decision Tree for risk-averse model

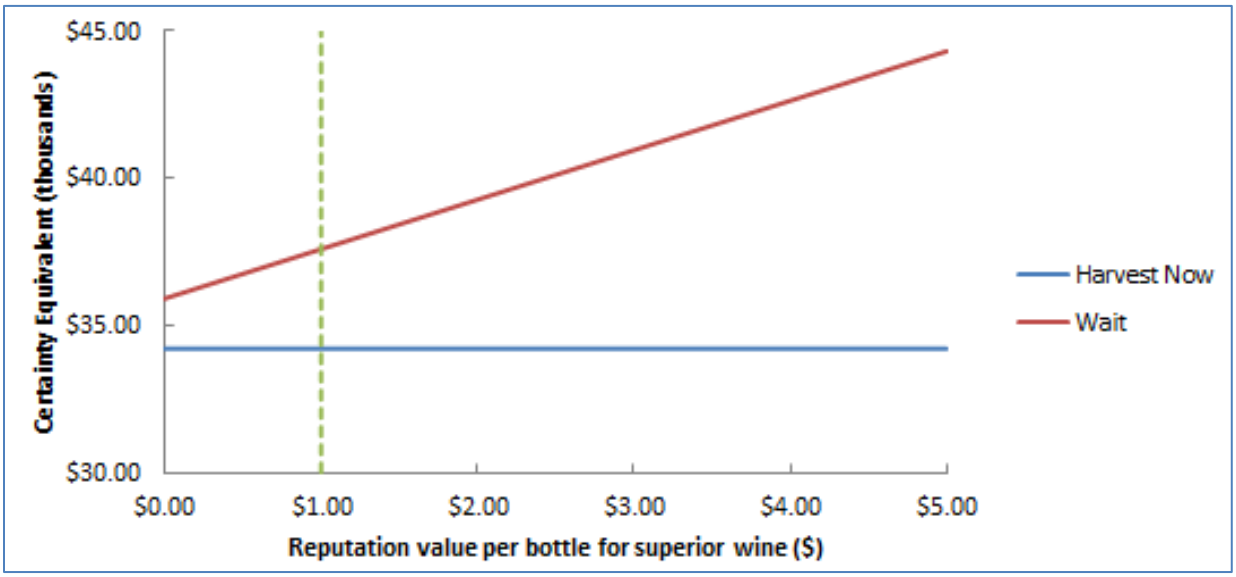



| Wine | Price per bottle | No. bottles (thousands) | Revenue (thousands) | Reputation per bottle | Net Revenue (thousands) | Utility |
|---|---|---|---|---|---|---|
| Not-quite-ripe | $2.85 | 12.0 | $34.2 | $0.00 | **$34.20** | **0.2897** |
| Complex Sweet | $8.00 | 8.4 | $67.2 | $1.00 | **$75.60** | **0.5305** |
| Thin | $2.00 | 12.9 | $25.8 | -$1.50 | **$6.45** | **0.0625** |
| None | NA | NA | $12.90 | $0.00 | **$12.90** | **0.1210** |
| Full Bodied | $3.50 | 12.0 | $42.0 | $0.00 | **$42.00** | **0.3430** |
| Light Bodied | $3.00 | 12.0 | $36.0 | $0.00 | **$36.00** | **0.3023** |
| Low Sugar | $2.50 | 12.0 | $30.0 | $0.00 | **$30.00** | **0.2592** |

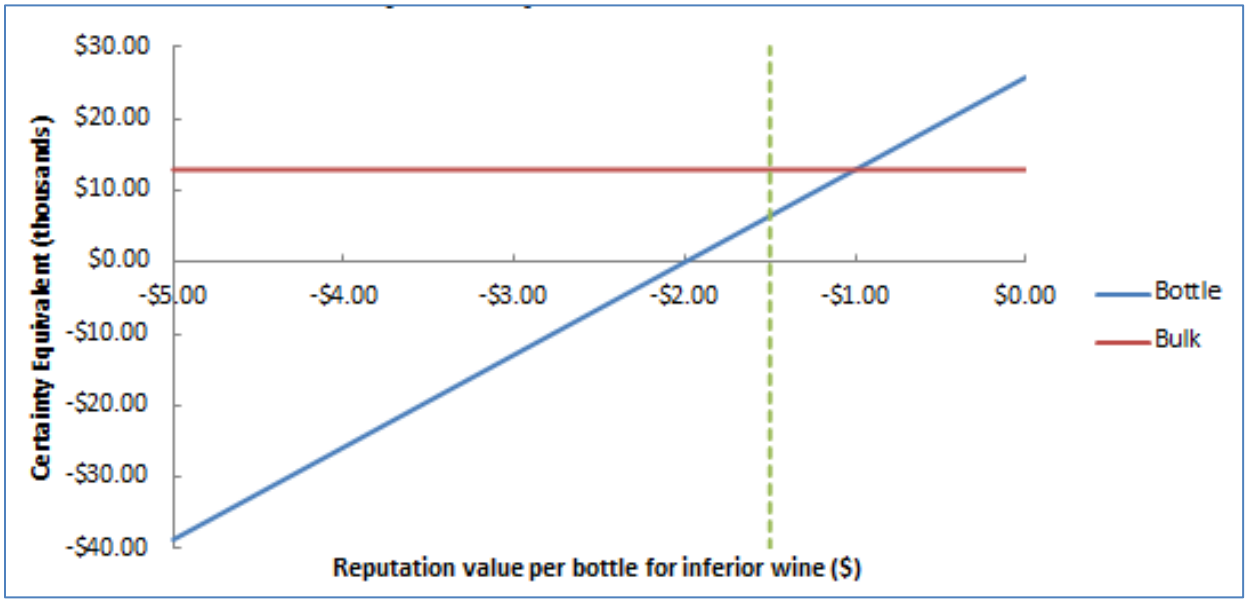
## Sensitivity to P(storm)



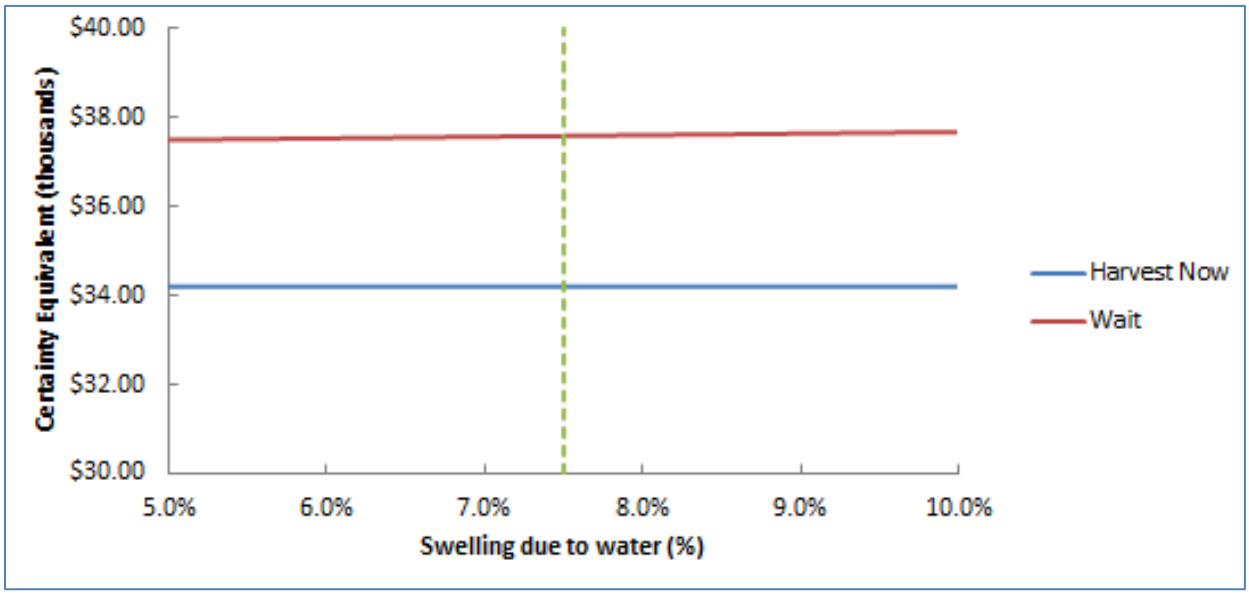
## Sensitivity to Reputation for superior wine



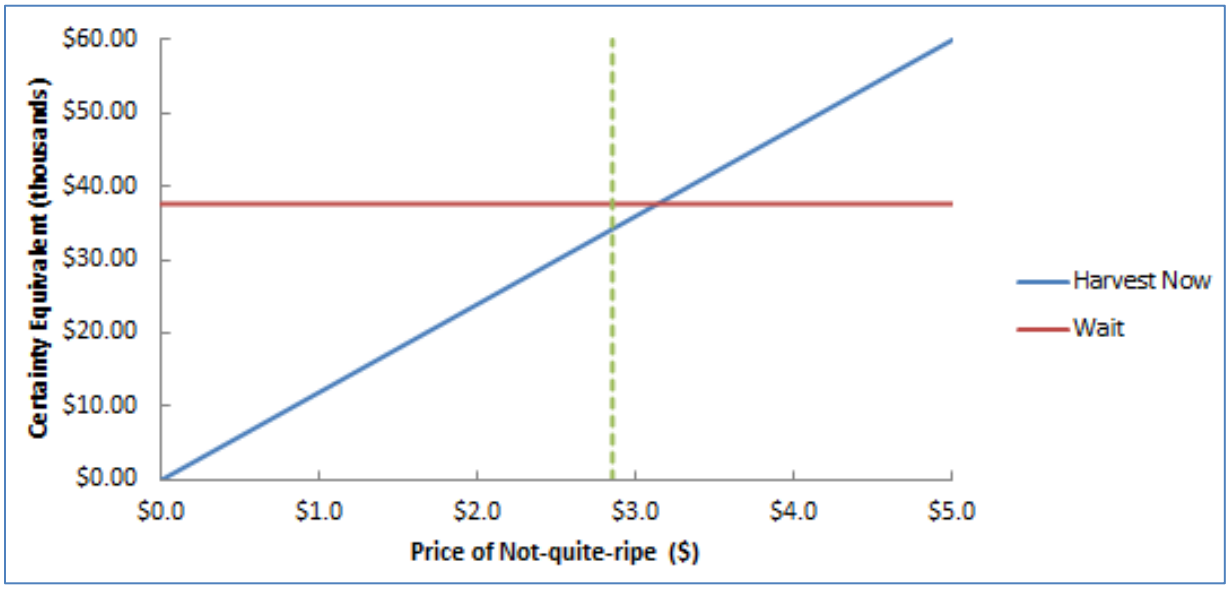

## Sensitivity to Reputation for inferior wine



## Sensitivity to Reputation for swelling due to water




## Sensitivity to Price of not-quite-ripe wine



## Sensitivity to P(Botrytis) of VPI