

Engineering Wine

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Overview

- **Background**
- **Process Overview**
- **Goals and Modeling Requirements**
- **Consumer Preference Model**
- **Financial Analysis**
- **Analysis Under Uncertainty**
- **Conclusions**



Background

History of Wine

- **Enjoyed by many civilizations**
- **Celebratory and ceremonial uses**
- **“Nectar of the Gods”**
- **Increasing desire of consumer satisfaction**



Wine Today

- **BEFORE:** Wine quality/characteristics influence by producer
- **NOW:** Consumers control wine quality
- **New tasks for producer**
 - Identify consumer wants
 - Adjust manufacturing
 - Adjust price



Solution

- **Identify consumer utility**
- **Manipulate process to meet desired quality**
- **Determine wine characteristics before bottling**
- **Meet profit aspiration**



Process Overview



Process Overview

Basic Process: 4 main steps

- **Harvest and Crushing**
- **Fermentation**
 - Reduction of sugar, increase in –OH
 - Malolactic Fermentation, decrease acidity
- **Clarification/Hot and Cold Stabilization**
- **Oak Aging**



Harvest and Crushing

- Cold soaking is where hue and brightness can be altered (color)
- Tannins extracted from seeds and grapes (bitterness)





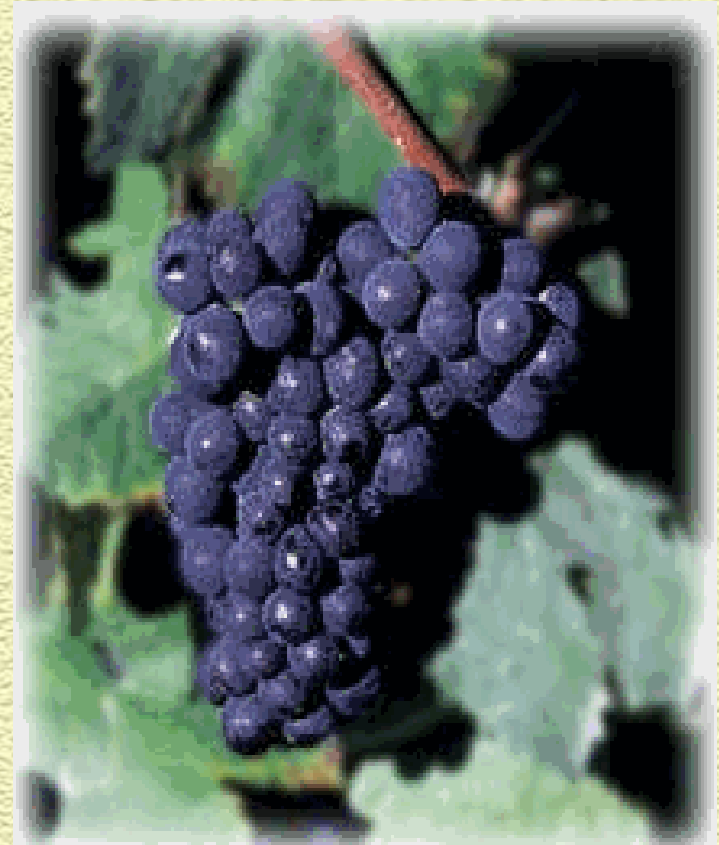
Fermentation and Clarification

- **Fermentation**
 - Increase in percent alcohol (body/texture)
 - Reduction in residual sugar (sweetness)
 - Increase fermentation time decreased acidity
- **Clarification/Hot and cold stabilization**
 - Clarity
 - Filtering



Aging: Natural Grape Aroma

- **Flowery aroma comes from β -damascenone**
- **Berry aroma associated with β -ionone**





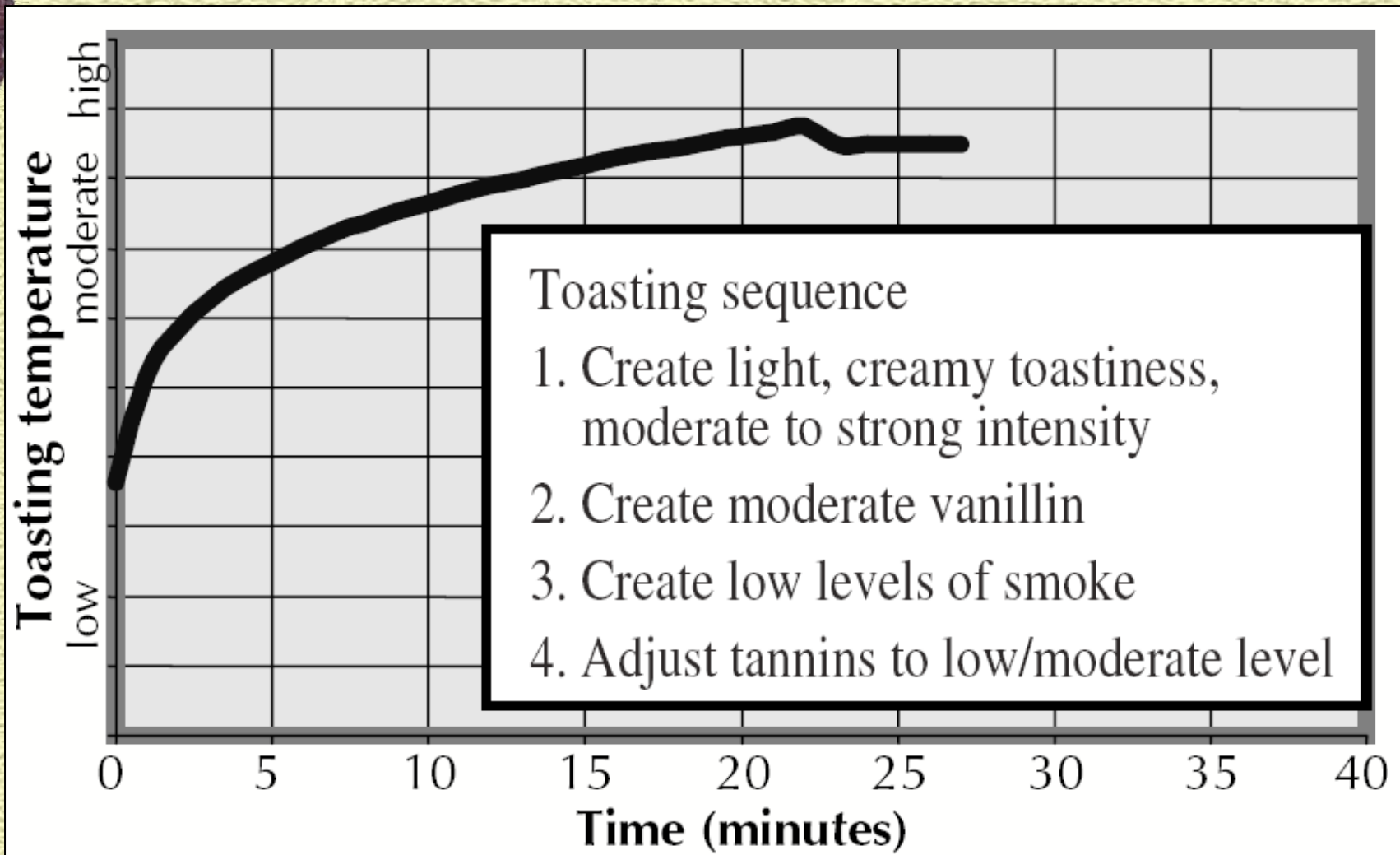
Toasting Effects

- **Barrel Heating**
 - **Open Flame**
 - **Time vs. Temperature Profiling**
 - **Toast Levels**
 - **Light**
 - **Medium**
 - **Medium Plus**
 - **Heavy**



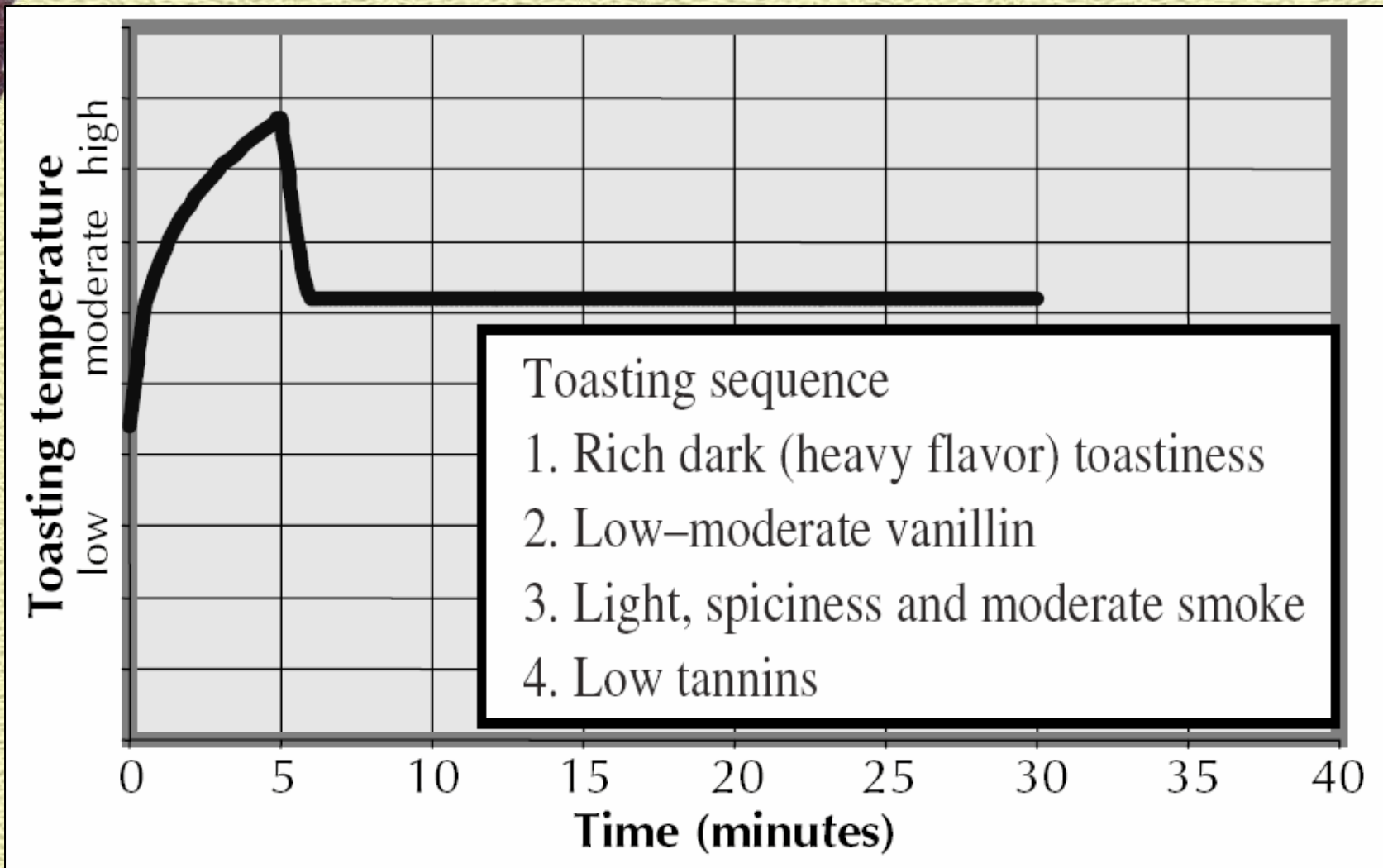


Time-Temperature Profile





Time-Temperature Profile





Compounds

- Cellulose and amino acids undergo Maillard reaction
 - Responsible for caramel, butterscotch flavor
- Lignin → Pyrolysis
 - Responsible for clove, vanilla flavor
- Oak and clove flavor from non-caramelized wood





Modeling Requirements



Goals

**Develop model for calculation of NPW
with inputs:**

- **Physical properties of the wine**
- **Selling price**
- **Competitor selling price**
- **Advertising level**
- **Consumer budget**



Demand Model

- **Satisfaction**
- **Maximize Satisfaction**
- **Consumer Budget**

$$S = \left(d_1^\rho + d_2^\rho \right)^{1/\rho}$$

$$p_1 d_1^{1-\rho} = \frac{\alpha}{\beta} p_2 d_2^{1-\rho}$$

$$Y \geq p_1 d_1 + p_2 d_2$$



Happiness Function

1. Happiness Function:

$$H_1 = \sum w_i y_i$$

2. Superiority Function:

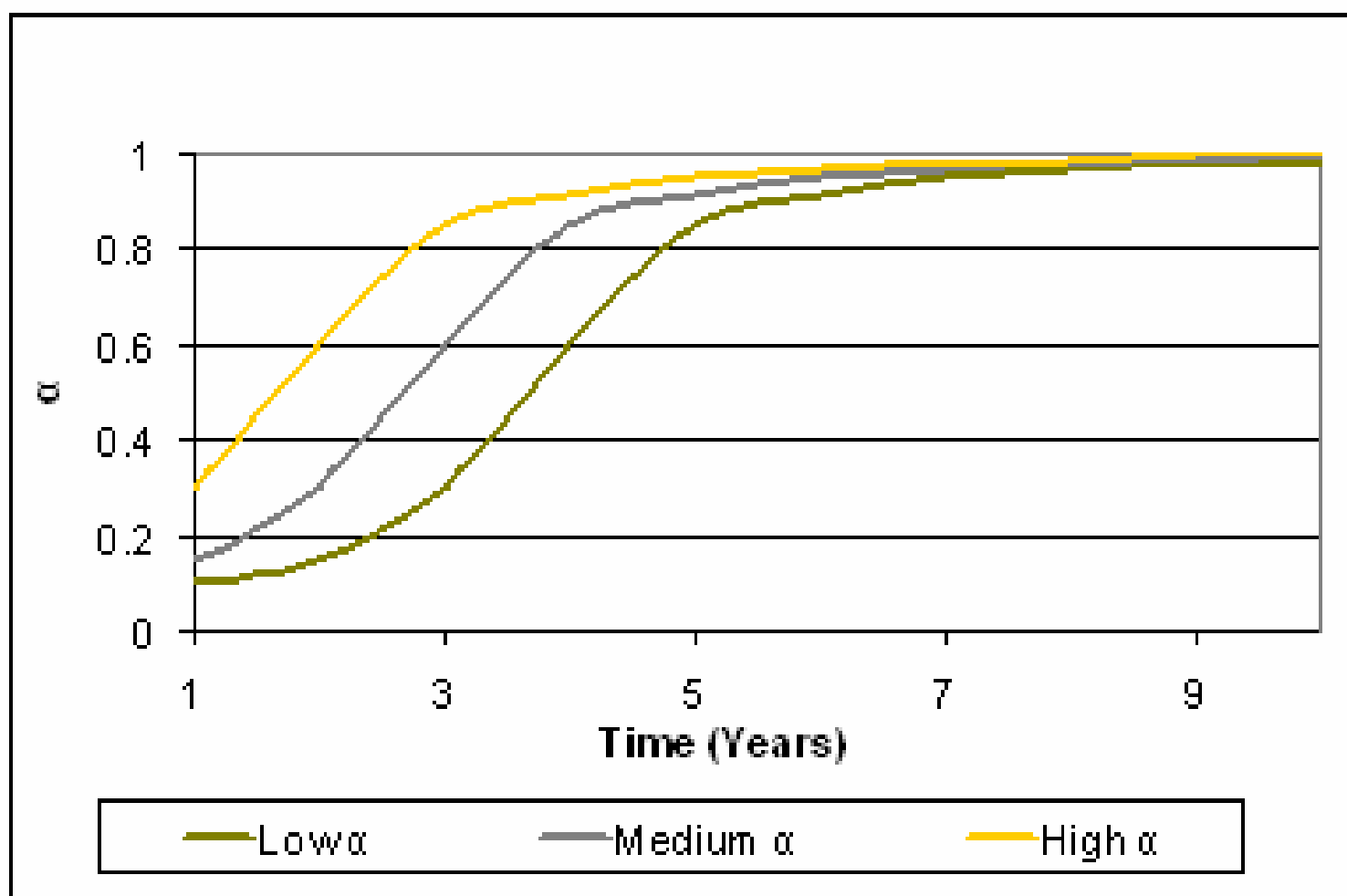
$$\beta = H_2 / H_1$$

3. Demand 1:

$$d_1 = \left(\frac{\alpha}{\beta} \right)^\rho \frac{p_2}{p_1} \left[\frac{Y - p_1 d_1}{p_2} \right]^{1-\rho} d_1^\rho$$



Advertising Levels





Consumer Preference Model



Wine Characteristics

- **Clarity**
- **Body/Texture**
- **Bouquet**
 - **Flowery**
 - **Berry**
 - **Vanilla**
 - **Butterscotch**
 - **Clove**
 - **Coconut/Oak**
- **Acidity**
- **Sweetness**
- **Bitterness**
- **Color**
 - **Hue**
 - **Brightness**



Consumer Preference

- Survey over sample population
- Determined relative importance of characteristics
- Resulted in values of w_i

Characteristic	w_i
Clarity	0.15
Color	
Hue	0.08
Brightness	0.08
Bouquet	0.30
Acidity	0.08
Sweetness	0.08
Bitterness	0.08
Body/Texture	0.15

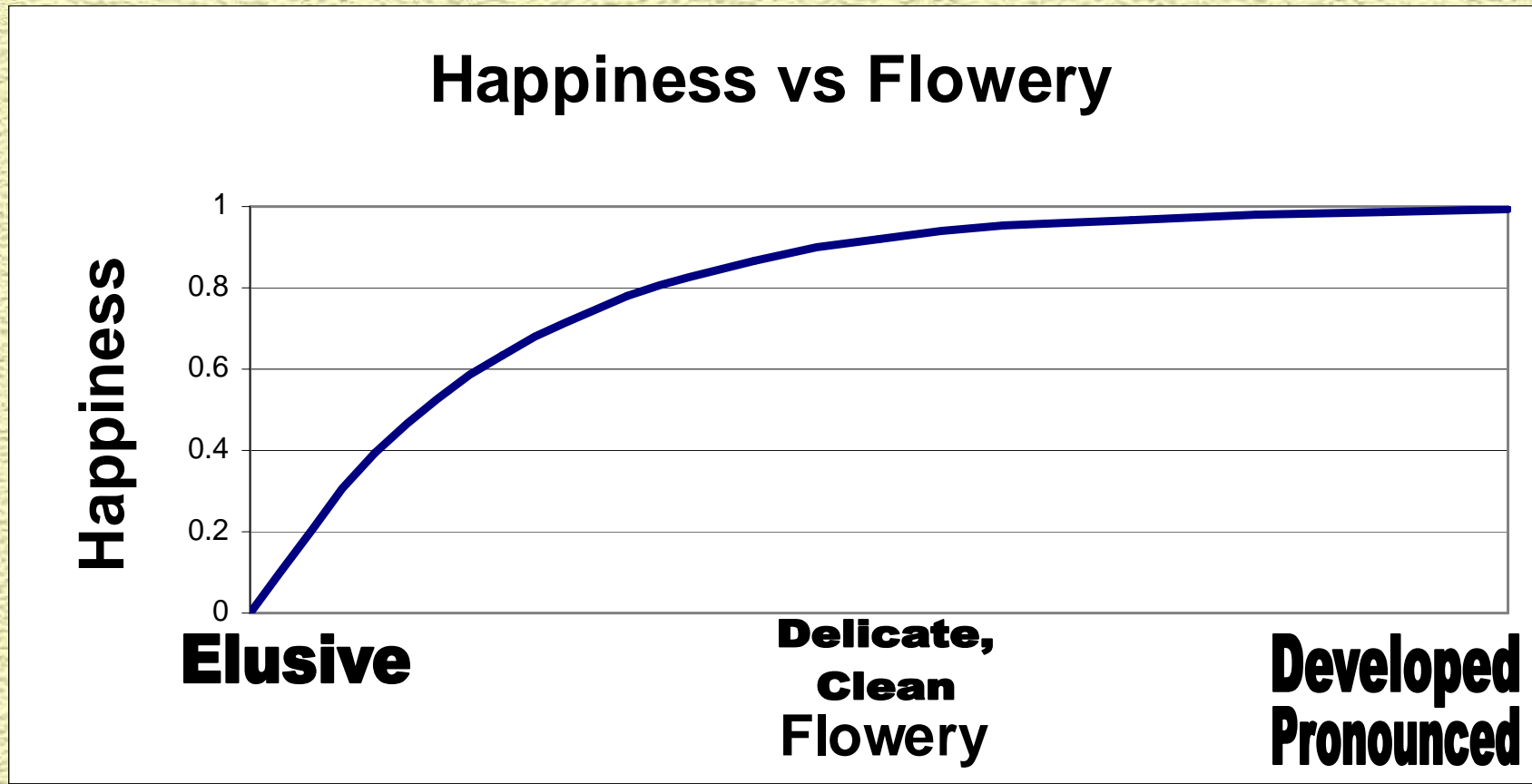


Happiness Curve: Bouquet-Flowery

- **Happiness related to consumer descriptions**
- **Descriptions related to amount of component**
- **Happiness description of Flowery components**



Example Flowery Preference Curve



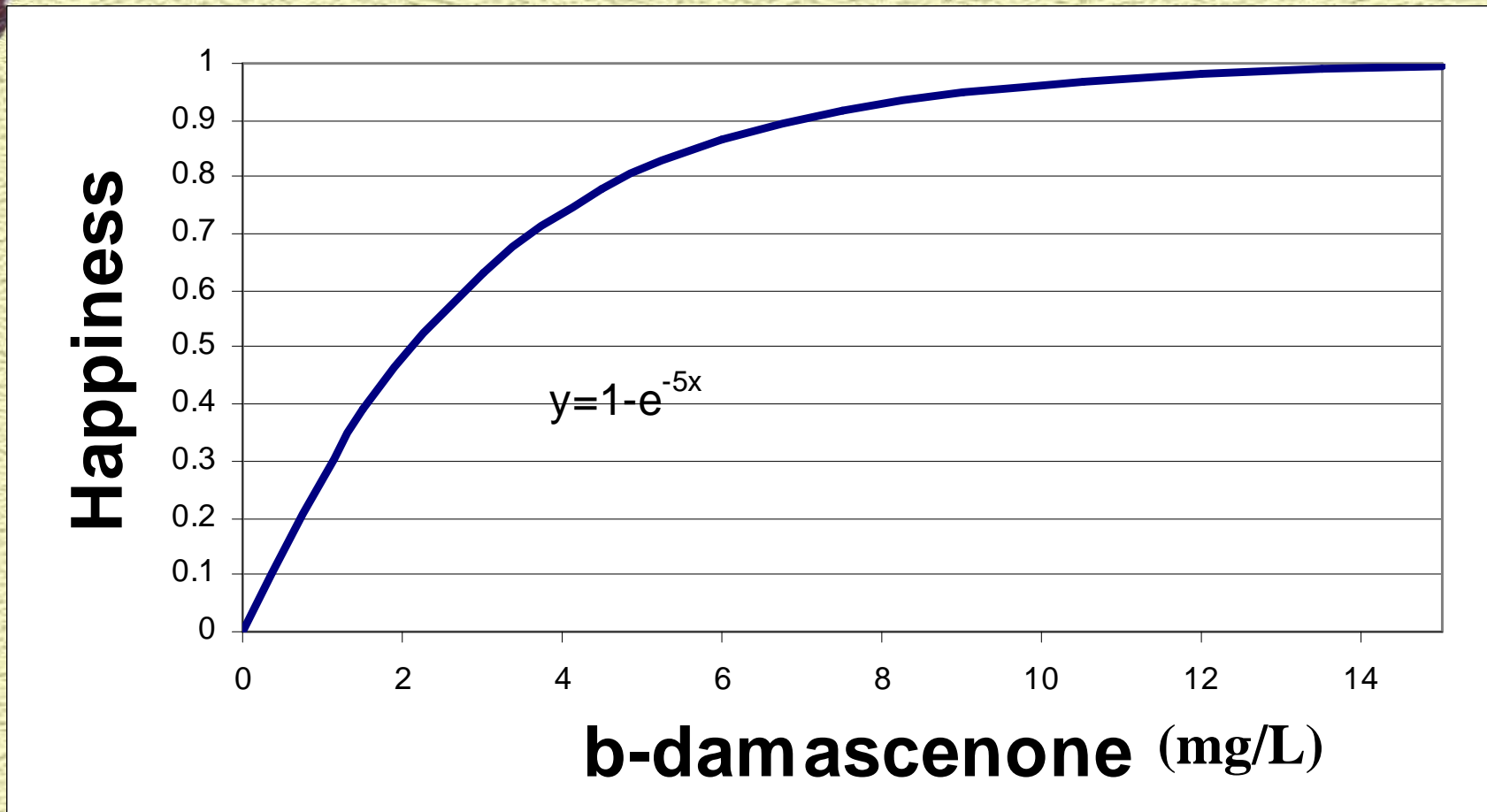


Flowery vs β -damascenone





Preference vs b-damascenone





Happiness-Perfect Bottle

Happiness	y_i	w_i
Aging Year	1	Weights
Production Year	2	
Clarity	0.78	0.153846
Color (Hue)	0.64	0.076923
Color (Brightness)	0.70	0.076923
Flowerly (b-damascenone)	1.00	
Berry (b-ionone)	1	
Vanilla (Vanillin)	0	
Clove (Eugenol)	0.19	
Butterscotch (Furfural)	0.1198	
Oak/Coconut (Lactones)	0.2153	
Combined Score of 6	0.42085	
Acidity	1.00	
Sweetness	1.00	
Bitterness	0.67	
Combined Score of 3	0.89	0.230769
Body	0.44	0.153846
Total Happiness (H_1)	0.62452	1.00

$$H_1 = \sum w_i y_i$$

$$\beta = H_2 / H_1$$



Financial Analysis



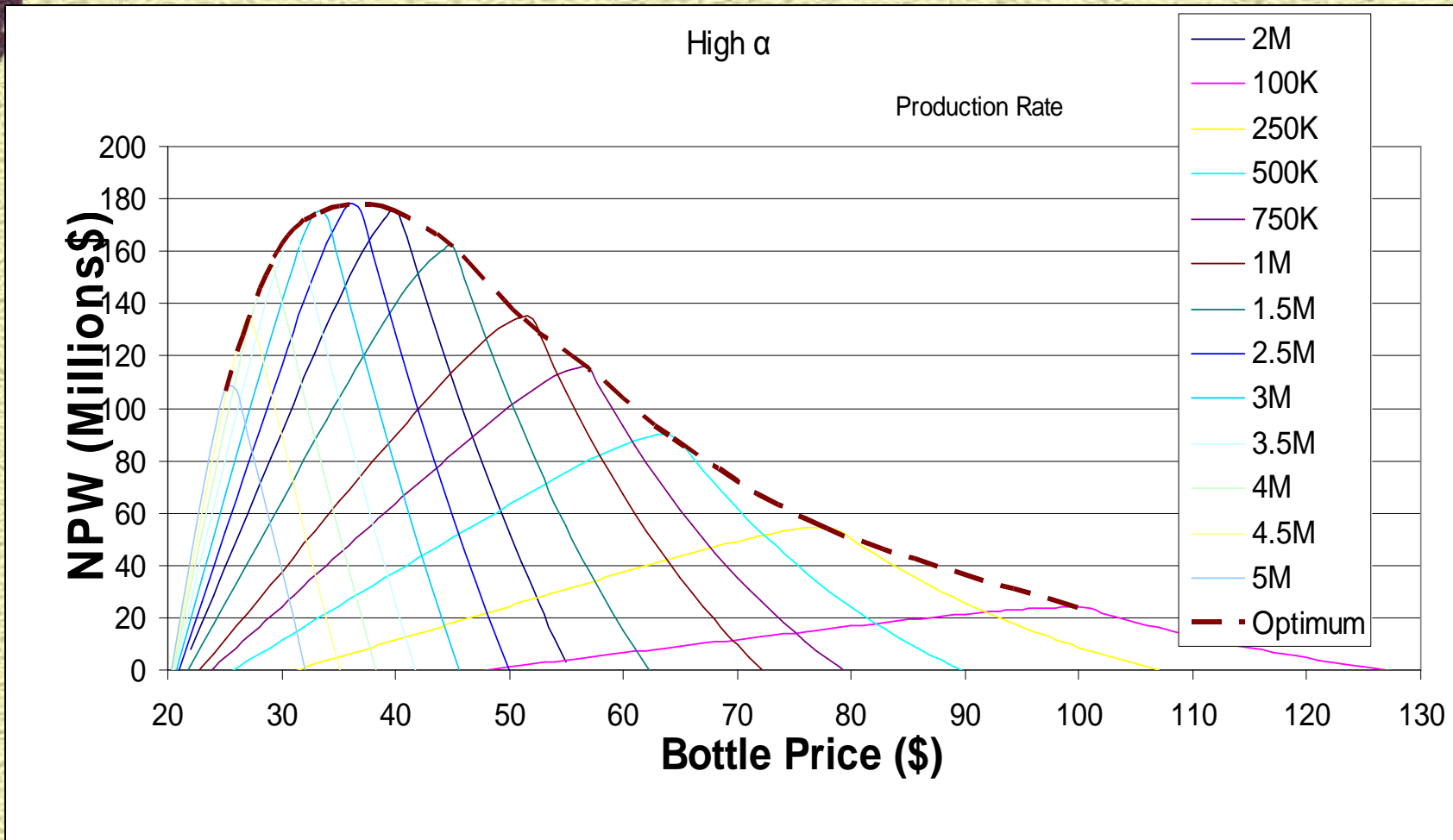
Final Product Desired

- For particular α level and β , find:
 - Optimum selling price p_1 at each production rate K , by:
 - Maximizing NPW, such that:

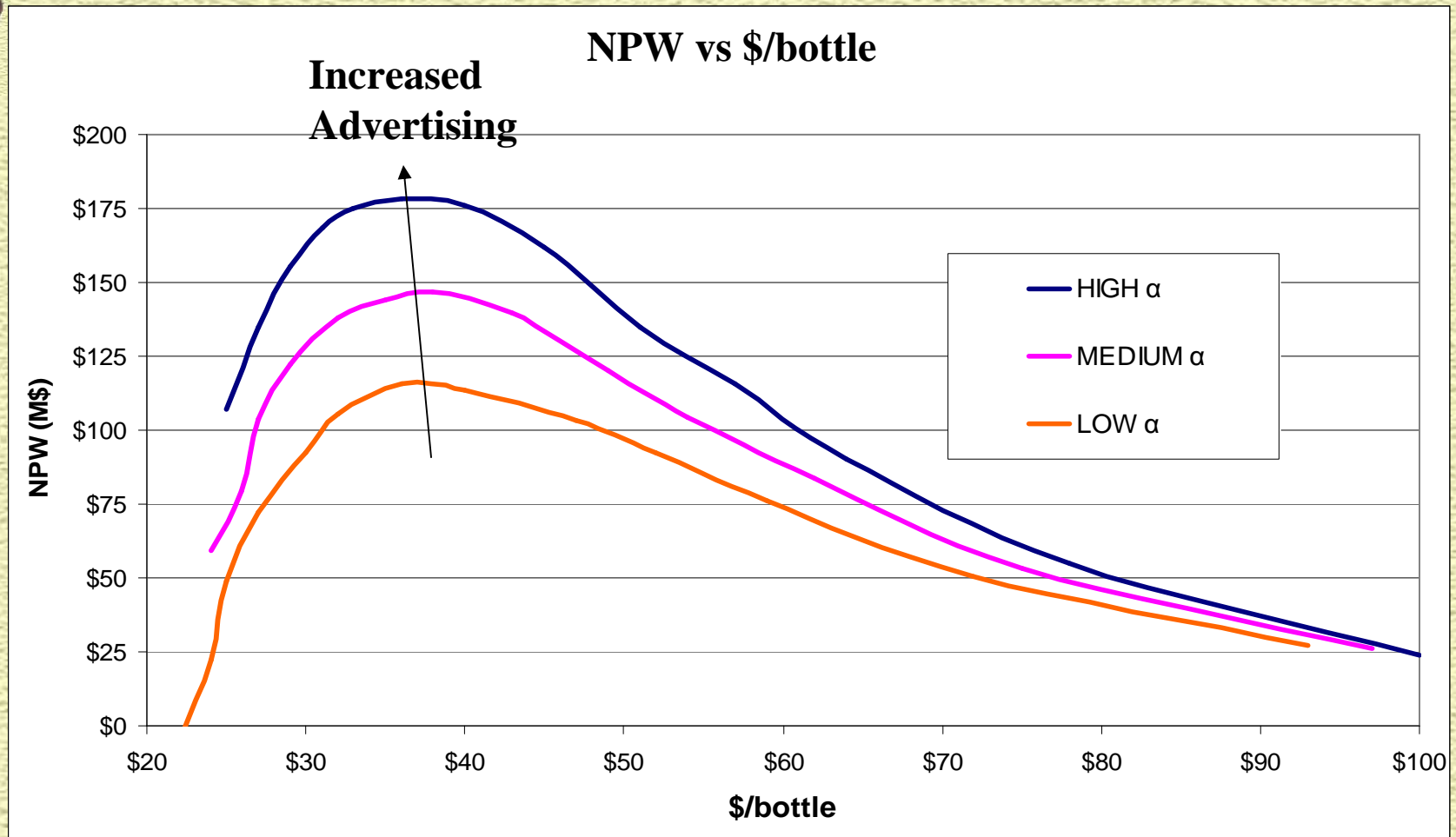
$$\Phi(d_1) = p_1 d_1 - \left(\frac{\alpha}{\beta}\right)^\rho p_2 \left[\frac{Y - p_1 d_1}{p_2}\right]^{1-\rho} d_1^\rho = 0$$



Financial Analysis: "Perfect Wine"



Engineering Wine





Analysis Under Uncertainty



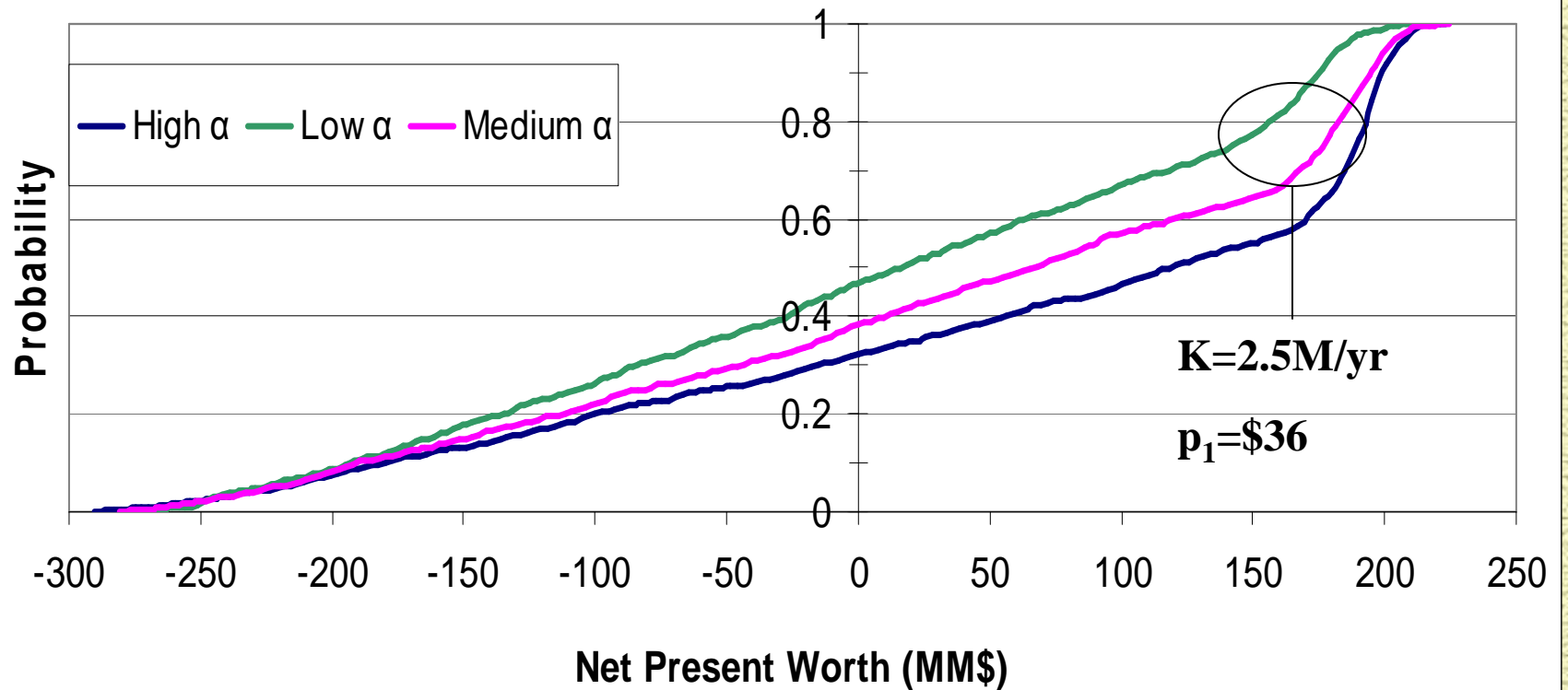
Uncertainty

- **Driving factor for quantifying risk**
- **Sensitivity analysis**
 - **Consumer happiness, H_2**
 - **Competitor price, P_2**
 - **Consumer budget, Y**
 - **Consumer happiness, H_1**
 - **Interest rate**

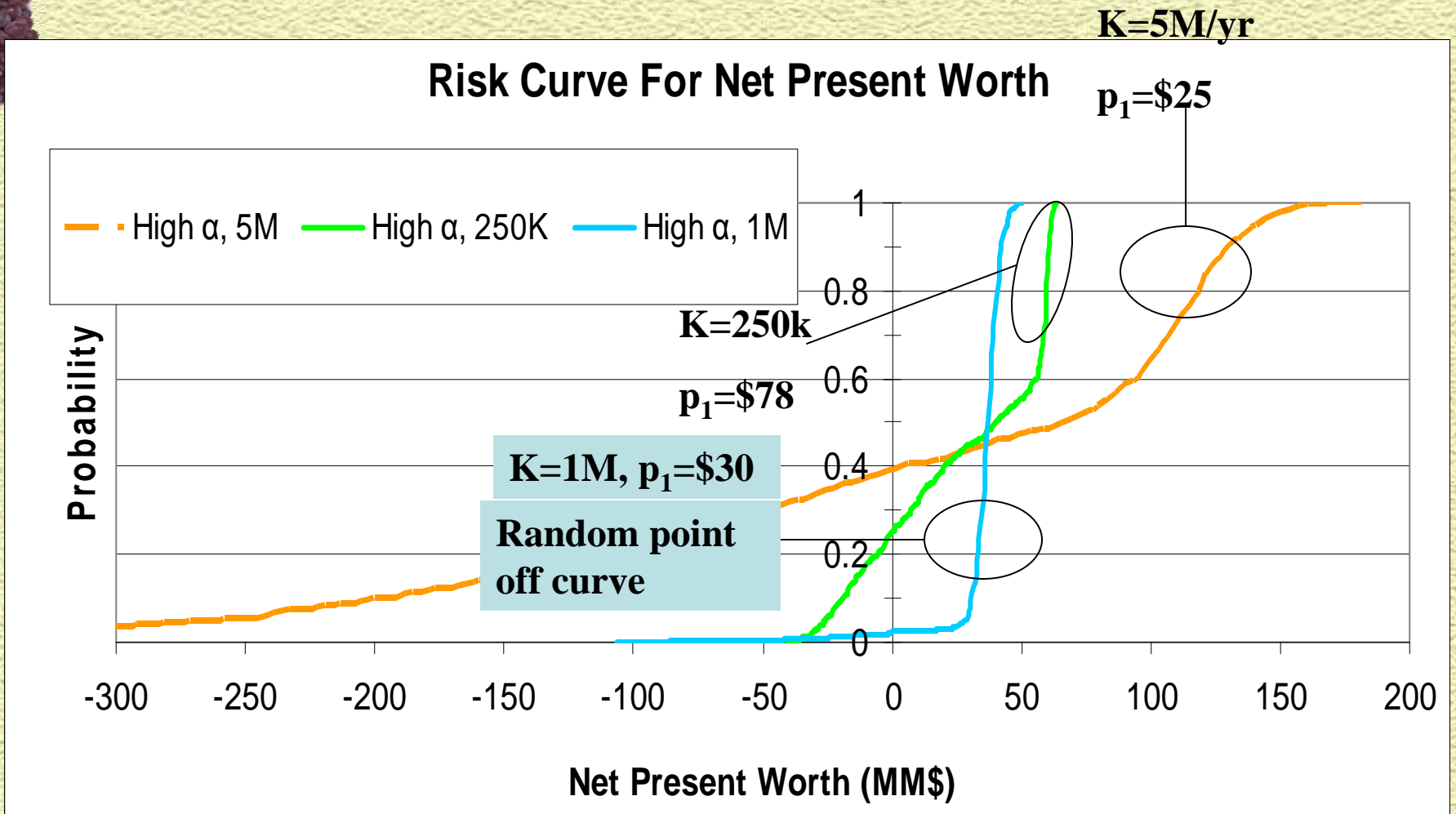


Initial Risk Analysis

Risk Curve For Net Present Worth

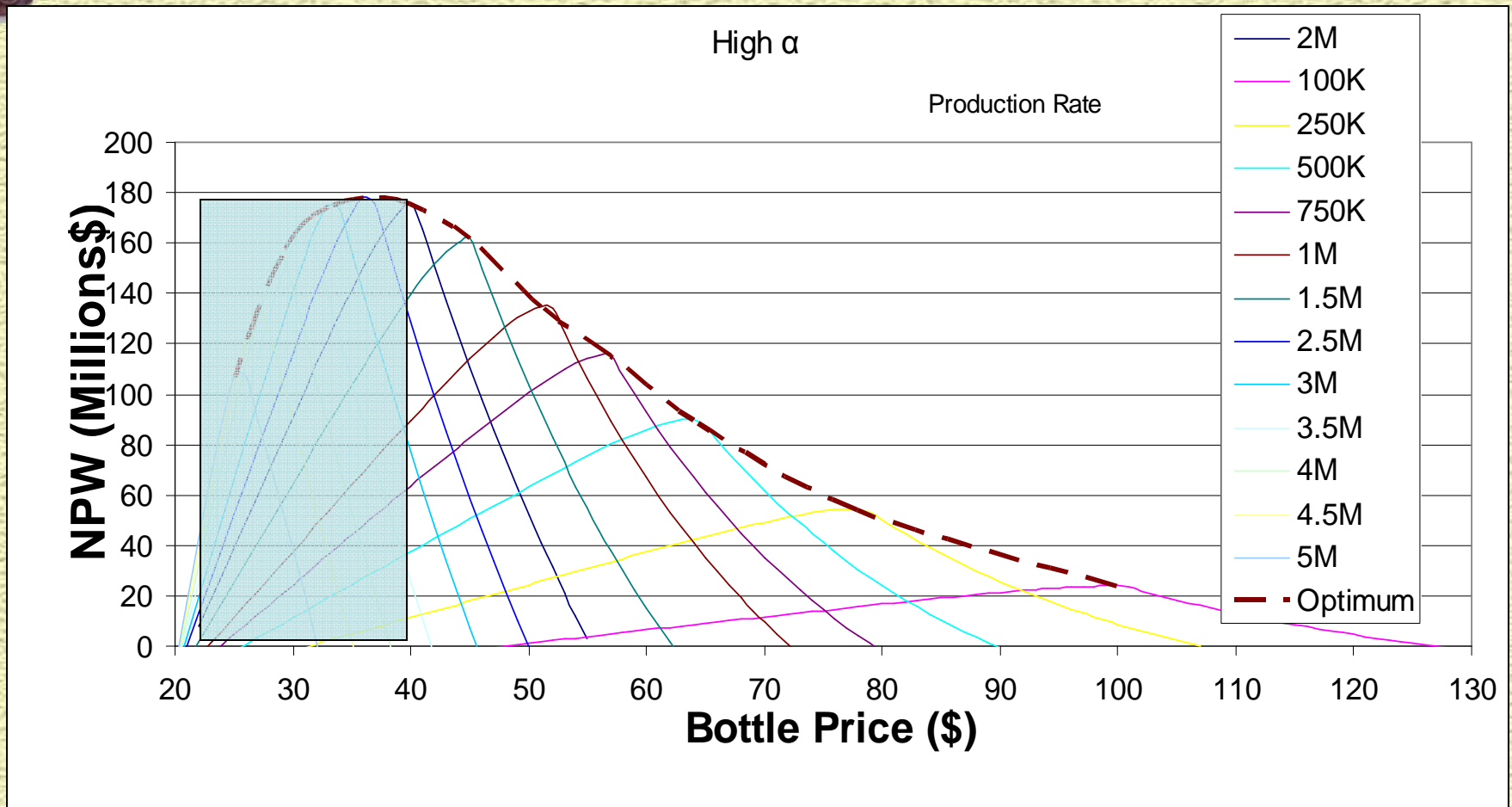


Initial Risk Analysis



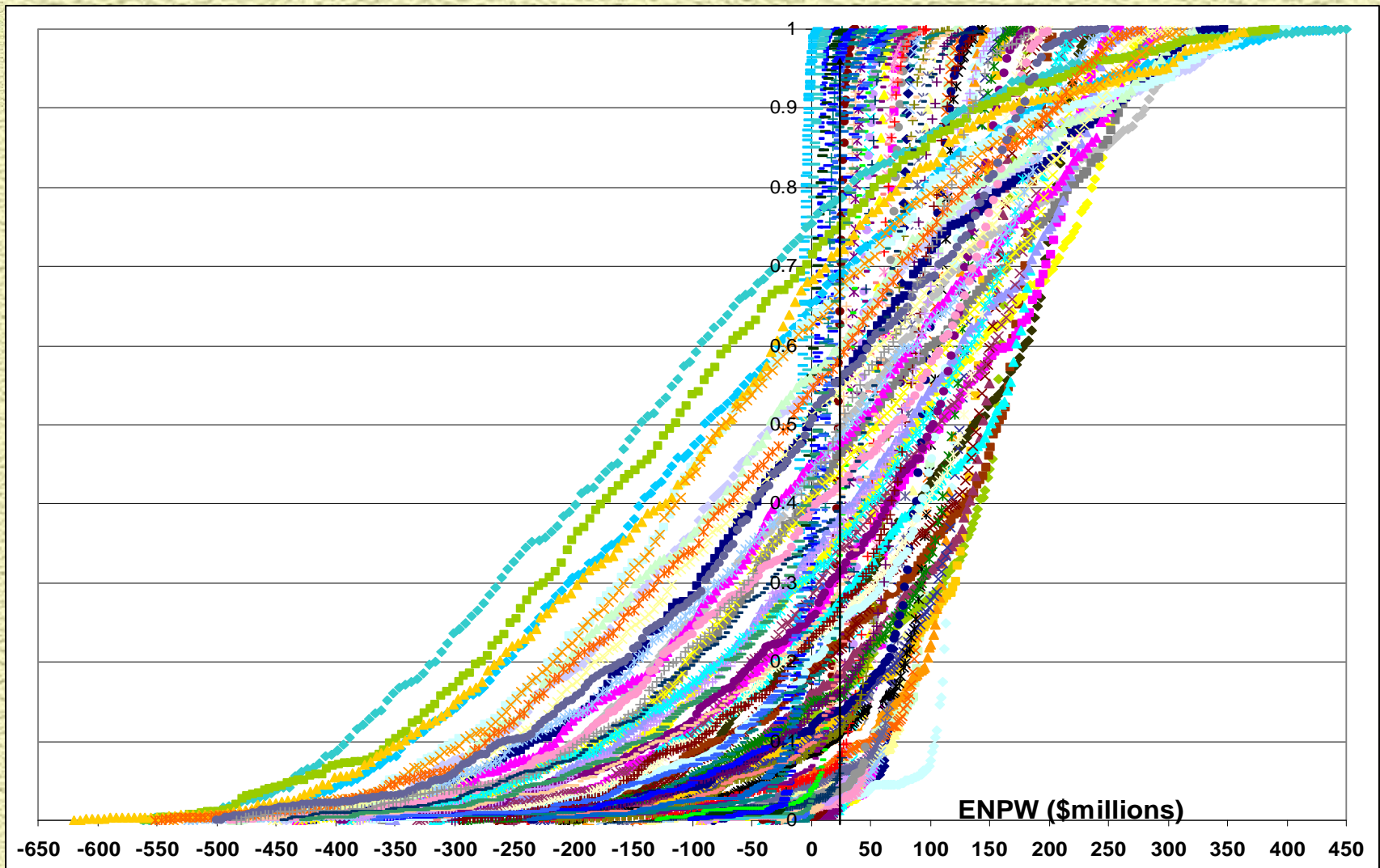


Complete Risk Analysis: “Perfect Wine”

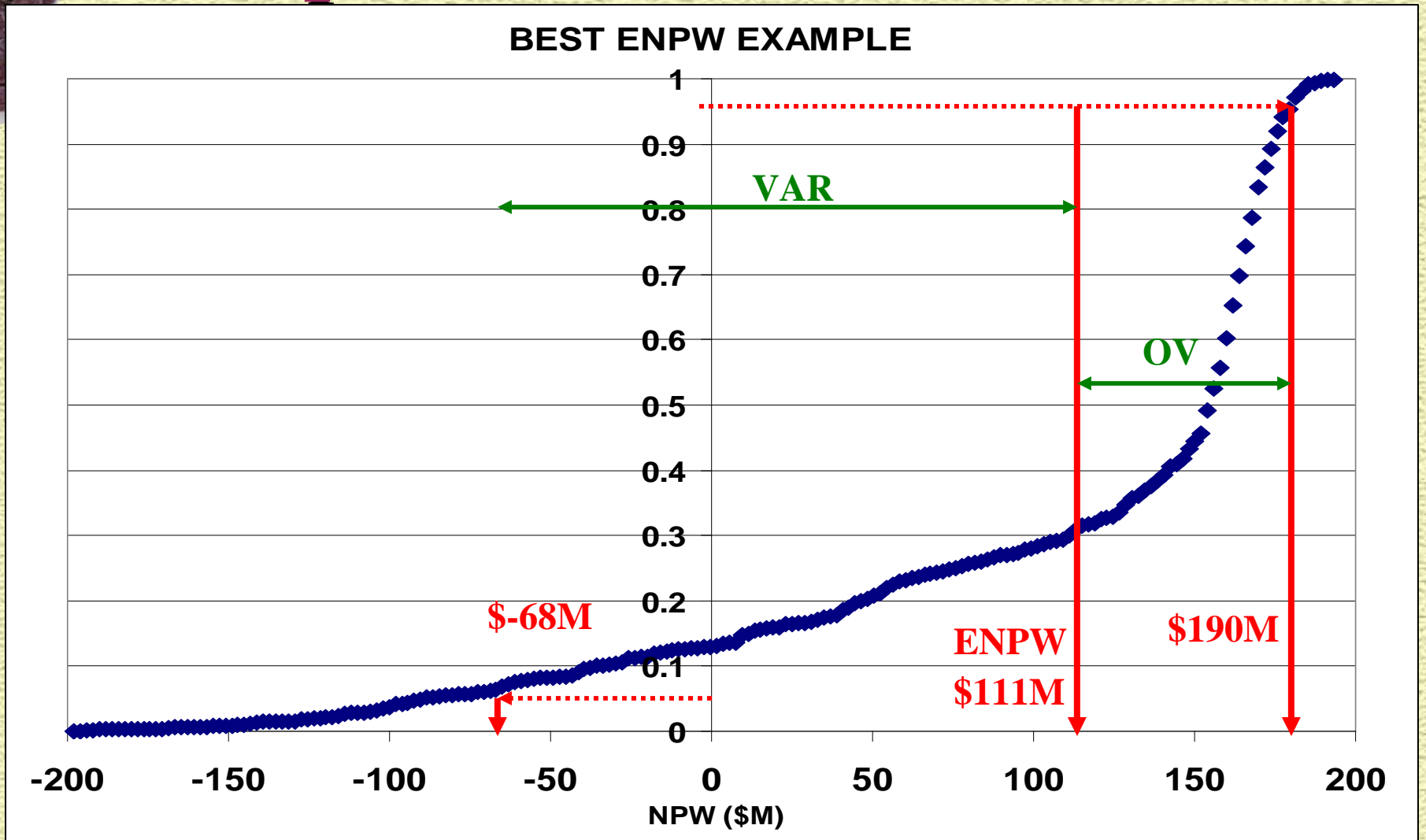




Risk Curves: “Perfect Wine”

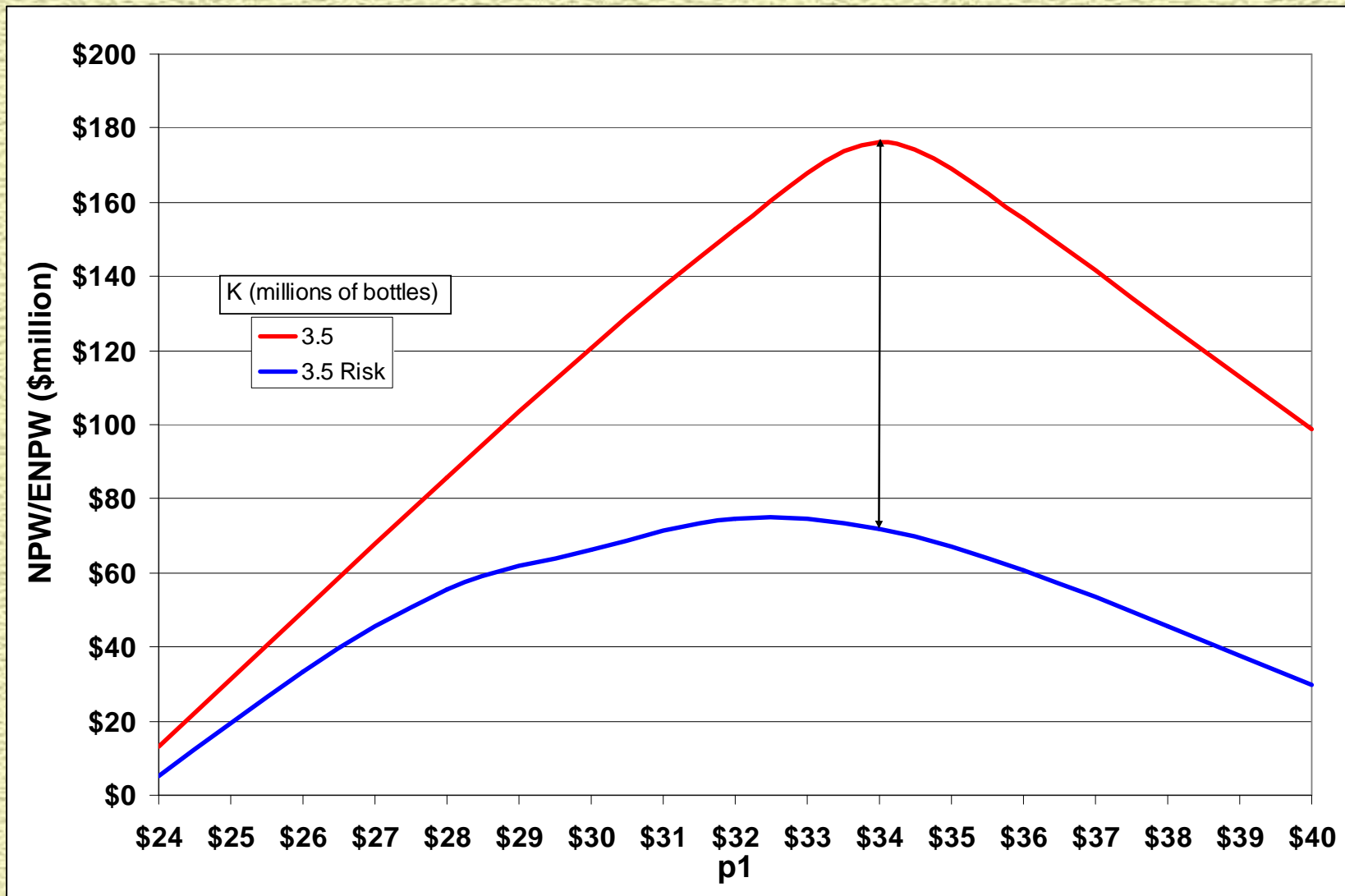


Example ENPW





Effect of Uncertainty

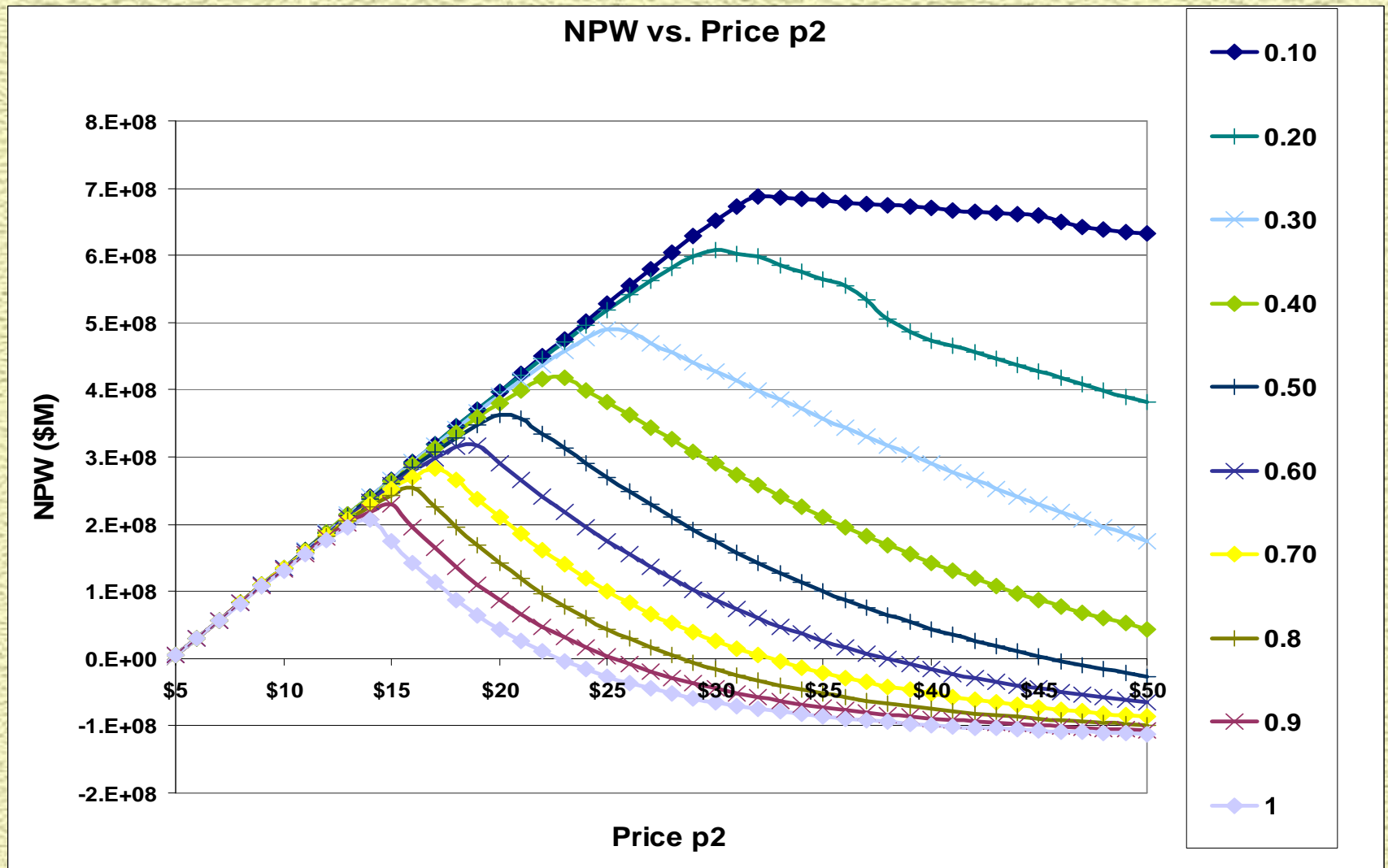




Wine Manipulation

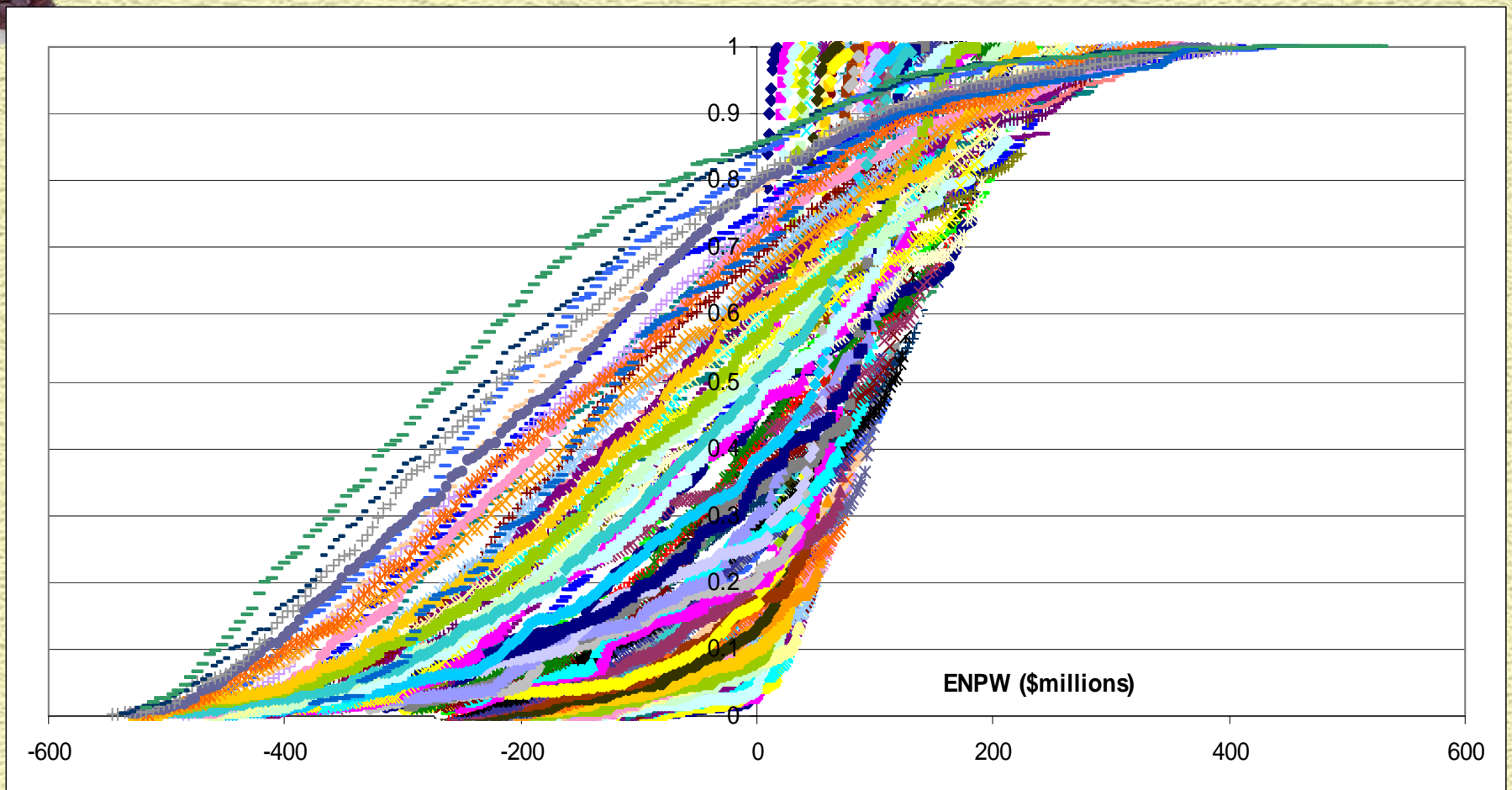


Wine Manipulation





Complete Risk Analysis: $\beta = 0.8$





Comparison: Perfect to $\beta = 0.8$

"Perfect Wine"								$\beta = 0.8$							
K (mil)	p1	NPW (\$M)	ROI	ENPW	? = 0	VAR (\$M)	OV (\$M)	K (mil)	p1	NPW (\$M)	ROI	ENPW	? = 0	VAR (\$M)	OV (\$M)
1.0	\$34	\$44	92%	\$43	1%	\$9	\$9	1.5	\$38	\$100	140%	\$42	28%	\$174	\$72
1.5	\$30	\$43	61%	\$41	1%	\$13	\$14	1.0	\$40	\$74	153%	\$41	20%	\$118	\$42
2.0	\$28	\$42	45%	\$39	3%	\$18	\$19	1.5	\$34	\$73	103%	\$39	20%	\$142	\$45
4.0	\$34	\$126	67%	\$38	41%	\$282	\$199	1.5	\$40	\$109	153%	\$38	33%	\$181	\$91
3.5	\$26	\$50	30%	\$33	10%	\$102	\$42	1.0	\$36	\$54	112%	\$36	14%	\$95	\$25
1.0	\$32	\$34	70%	\$33	1%	\$8	\$8	2.0	\$34	\$99	105%	\$32	31%	\$195	\$82
3.0	\$26	\$40	28%	\$31	8%	\$49	\$31	1.5	\$32	\$58	82%	\$31	17%	\$138	\$38
3.5	\$40	\$99	60%	\$30	44%	\$287	\$269	2.0	\$32	\$81	86%	\$30	27%	\$186	\$67
4.0	\$26	\$59	32%	\$29	18%	\$136	\$55	1.0	\$34	\$44	92%	\$28	14%	\$100	\$24
2.5	\$26	\$30	26%	\$26	4%	\$22	\$23								
1.5	\$28	\$27	39%	\$26	1%	\$14	\$13	1.5	\$30	\$43	61%	\$25	13%	\$127	\$33
4.5	\$28	\$108	52%	\$25	33%	\$231	\$117	2.0	\$30	\$62	66%	\$24	23%	\$153	\$51
4.0	\$36	\$97	52%	\$23	45%	\$305	\$246								
1.0	\$30	\$23	48%	\$23	0%	\$9	\$8								
4.5	\$30	\$122	58%	\$21	39%	\$280	\$160								
2.0	\$26	\$21	22%	\$20	4%	\$17	\$17	2.0	\$38	\$96	102%	\$19	43%	\$207	\$136
4.5	\$26	\$67	32%	\$16	25%	\$209	\$77	1.0	\$30	\$23	48%	\$18	8%	\$38	\$13
1.0	\$28	\$13	26%	\$12	2%	\$9	\$9	2.5	\$28	\$55	47%	\$12	25%	\$189	\$62
1.5	\$26	\$12	16%	\$11	7%	\$13	\$13								
4.5	\$32	\$95	45%	\$11	45%	\$311	\$208	2.5	\$32	\$99	84%	\$10	38%	\$230	\$111
3.5	\$24	\$13	8%	\$5	29%	\$43	\$33	2.0	\$26	\$21	22%	\$7	17%	\$83	\$28
3.0	\$24	\$9	6%	\$3	33%	\$29	\$28	1.5	\$26	\$12	16%	\$4	17%	\$50	\$19
2.5	\$24	\$4	3%	\$2	41%	\$20	\$19	2.5	\$26	\$30	25%	\$2	21%	\$168	\$44



Conclusions

- **Quality of the wine can be manipulated at negligible costs**
- **Uncertainty needs to be incorporated in order to make accurate decisions based on level of risk**
- **Risk can be adjusted by the adjustment of wine quality**



Acknowledgements

- Dr. Miguel Bagajewicz, University of Oklahoma
- Phillip Coghill, TA
- Susan Kerr
- Michael Frow
- Curtis Baade

Questions?

A scenic view of a vineyard with a stone wall in the foreground and rolling hills in the background. The image is slightly faded, and the text 'Questions?' is overlaid in the center.