# PRODUCTION AND MARKETING RISKS ASSOCIATED WITH WINE GRAPES IN WASHINGTON

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# PRODUCTION AND MARKETING RISKS ASSOCIATED WITH WINE GRAPES IN WASHINGTON

**by**

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## INTRODUCTION

The Washington wine grape producing region has many similarities to other prominent wine grape producing areas throughout the world. The desirable climate conditions during the growing season and cold temperatures during the winter months help the vines achieve full dormancy. However, the low wintertime temperatures can kill buds and sometimes the vine itself. Bud kill is a major production risk that can reduce the tonnage the grower harvests and the profit level realized. This type of risk has occasionally precluded the investment in wine grape vineyards in Washington.

There are also marketing risks in terms of price variations or a lack of demand for certain varieties. Marketing risks are directly reflected in the price levels for the numerous varieties. Production and market risks are related. For example, bud kill can affect the price by reducing supply, thus increasing the price the producer is paid. However, higher prices may not compensate for reduced yield and, therefore, lower the producer's returns.

The overall objective of this research was to conduct an economic analysis which accounts for both production and market risks of Cabernet Sauvignon, Chenin Blanc, and White Riesling wine grape vineyards in Washington. The production risk addressed is in terms of low wintertime temperatures killing the fruiting buds and lowering yields. The market risk is in terms of resulting price variation as the market supply and demand changes. To account for both risks in a simultaneous fashion, a computer simulation model was constructed which combines weather (temperature) impacts on bud kill and yields which in turn impacts prices through price flexibility coefficients and costs of production. The simulation model was run 2,000 times over the assumed life of 19 years of a vineyard to determine the average net returns, internal rate of return (IRR), net present value (NPV), and investment payback period by variety planted.

The analysis assumes that the producer does not employ any type of risk management strategies. Examples of such strategies would be the use of wind machines for possible protection against low winter temperatures or forward contracting at fixed prices to reduce market price variability.

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## METHODS

The computer simulation model consisting of nine components (Figure 1) was run under seven different critical temperatures for bud kill and price scenarios (Table 1). The first component of the model involved the daily low temperatures during the months of December, January, and February for Prosser, Washington, from 1937 through 1993. A probability distribution function (PDF) of the daily temperatures for each month was constructed. By summing the individual monthly probability distribution function values, a cumulative distribution function (CDF) for each month was developed.

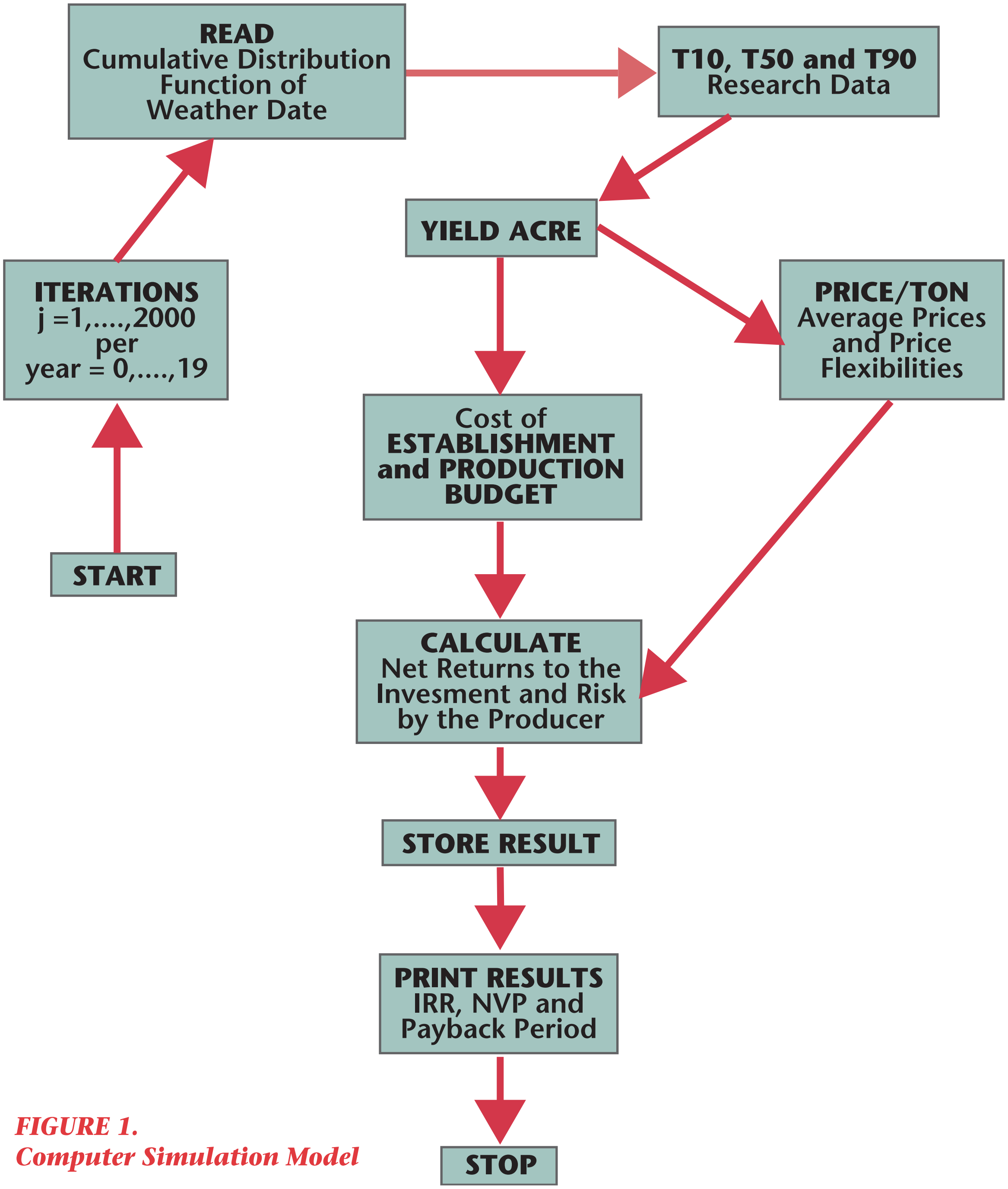

*FIGURE 1.*
*Computer Simulation Model*

***TABLE 1.***

***Prices and Critical Temperatures Used in the Various Simulation Model Scenarios by Variety***

| | | Critical $T_{10}$ Temperature (°F) [1] | | |
|---|---|---|---|---|
| Variety/Scenario | Price ($/ton) | December | January | February |
| **Cabernet Sauvignon** | | | | |
| Base | | | | |
| | 874.67 | Not Applicable[2] | | |
| 1 | 874.67 | -16.37 | -18.63 | -16.73 |
| 2 | 796.23 | -16.37 | -18.63 | -16.73 |
| 3 | 953.01 | -16.37 | -18.63 | -16.73 |
| 4 | 874.67 | -14.11 | -16.64 | -13.69 |
| 5 | 796.23 | -14.11 | -16.64 | -13.69 |
| 6 | 953.01 | -14.11 | -16.64 | -13.69 |
| **Chenin Blanc** | | | | |
| Base | 395.33 | Not Applicable[2] | | |
| 1 | 395.33 | -15.90 | -17.01 | -15.26 |
| 2 | 380.86 | -15.90 | -17.01 | -15.26 |
| 3 | 409.80 | -15.90 | -17.01 | -15.26 |
| 4 | 395.33 | -13.44 | -14.28 | -12.21 |
| 5 | 380.86 | -13.44 | -14.28 | -12.21 |
| 6 | 409.80 | -13.44 | -14.28 | -12.21 |
| **White Riesling** | | | | |
| Base | 379.00 | Not Applicable[2] | | |
| 1 | 379.00 | -19.12 | -21.58 | -19.75 |
| 2 | 372.75 | -19.12 | -21.58 | -19.75 |
| 3 | 385.25 | -19.12 | -21.58 | -19.75 |
| 4 | 379.00 | -17.46 | -20.46 | -17.72 |
| 5 | 372.75 | -17.46- | | |
| 6 | 385.25 | -17.46 | -20.46 | -17.72 |

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***[1] $T_{10}$ indicates the temperature at which 10 percent of the fruiting buds are killed.***

***[2] In the base scenario it was assumed there was no bud kill.***

A CDF gives the probability that a random variable X is less than or equal to some value $X_0$ and is obtained by summing the PDF values for all X less than or equal to $X_0$. The CDF along with a uniform random number generator was used to generate random temperature observations which have the same probabilities as the empirical PDF. The simulation model contained a random number generator which was used to select a value between 0 to 1. This random number between 0 and 1 was matched to the CDF which also had values from 0 to 1 to select the temperature for each month. If the number generated did not exactly match the CDF, then a temperature was interpolated using the formula:

$$IT = \frac{N - Lcdf}{Hcdf - Lcdf} * (HT - LT) + LT$$

**where:**

**IT = interpolated temperature;**
**N = number selected by the random number generator;**
**Hcdf = the CDF which is higher than the number selected;**
**Lcdf = the CDF which is lower than the number selected;**
**HT = the temperature corresponding with the high CDF; and**
**LT = the temperature corresponding with the low CDF.**

Using this formula, a temperature value was created between the temperatures corresponding with one higher and one lower CDF for the number selected by the random number generator. One temperature was selected for each month of December, January, and February using this process. This was done during years 1 through 19 (the life of the vineyard).

The above simulation of the historical weather pattern was used to create the distributions of low temperatures that occurred each month. The use of a random number generator selected the temperatures for each month based upon a random selection from the weather distribution. Therefore, it was not assumed that the low temperatures were normally distributed, but rather distributed according to the actual historical pattern which the research was attempting to simulate.

The second component of the simulation model was the temperature at which 10, 50, and 90 percent ($T_{10}$, $T_{50}$, and $T_{90}$) of the fruiting buds were killed. The temperature rates were collected at the Irrigated Agriculture Research and Extension Center in Prosser, Washington, from 1988 to 1993. An ordinary least-squares regression (OLS) was estimated for each winter month with the log of percent primary bud kill as the dependent variable and the month's low temperature as the independent or explanatory variable (Table 2). The means and standard deviations for each temperature by month are reported in Table 3. If the temperature was higher than two standard deviations from the mean, then no bud kill was assumed. If there was bud kill in one month, it could also happen again in another month. For instance, if a 10 percent bud kill occurred in December and a temperature takes place in February where 30 percent of the buds are killed, then 30 percent of the 90 percent left alive after December were assumed destroyed in February. When no temperatures occur that caused bud kill, then the average yield for that year was used.

An average yield was used in the simulation model except when there was bud kill. The average yields during the establishment years and when the vineyard is mature are acceptable from a viticultural viewpoint to maintain a healthy vine over the life of a vineyard (Table 4). These average yields are based upon no bud kill. To adjust for bud kill, an OLS regression equation was estimated (Table 5). The equations were used to predict the difference or change in yield based upon the percent of primary bud kill.

*TABLE 2. Ordinary Least-Squares Linear Regression of Log of T Rates by Variety*

| Month | Explanatory Variable | | Adjusted $R^2$ |
|---|---|---|---|
| | Constant | Temperature | |
| | | —Cabernet Sauvignon— | |
| December | -0726.78 | -0.10564 | .5532 |
| | (-1.72) | (-5.43) | |
| January | -1.48364 | -0.13129 | .5980 |
| | (-3.23) | (-6.64) | |
| February | -0.61531 | -0.09625 | .4644 |
| | (-1.21) | (-4.28) | |
| | | —Chenin Blanc— | |
| December | -0.67148 | -0.10259 | .6126 |
| | (-1.83) | (-6.11) | |
| January | -1.05958 | -0.11442 | .6617 |
| | (-3.02) | (-7.60) | |
| February | -0.62593 | -0.09875 | .6672 |
| | (-1.78) | (-6.25) | |
| | | —White Riesling— | |
| December | -1.31954 | -0.12326 | .5573 |
| | (-2.50) | (-5.47) | |
| January | -2.94769 | -0.18236 | .6671 |
| | (-5.02) | (-7.69) | |
| February | -1.93890 | -0.14485 | .6081 |
| | (-3.13) | (-5.66) | |

*NOTE: Student's t-values appear in parentheses.*

*TABLE 3. T-Rate Temperature Mean and Standard Deviation by Month by Variety*

| Month | Mean Temperature of T Rates (°F) $T_{10}$ | $T_{50}$ | $T_{90}$ |
|---|---|---|---|
| | —Cabernet Sauvignon— | | |
| December | -18.627 | -22.169 | -23.889 |
| | (2.2592) | (1.8605) | (1.8965) |
| January | -20.611 | -23.558 | -25.172 |
| | (1.9856) | (1.3942) | (1.2160) |
| February | -19.779 | -22.950 | -24.794 |
| | (3.0458) | (1.8509) | (1.5736) |
| | —Chenin Blanc— | | |
| December | -18.362 | -22.275 | -24.356 |
| | (2.4599) | (1.6818) | (1.8220) |
| January | -19.746 | -23.505 | -25.462 |
| | (2.7334) | (1.0726) | (0.8851) |
| February | -18.313 | -22.555 | -25.125 |
| | (3.0534) | (1.4139) | (1.0788) |
| | —White Riesling— | | |
| December | -20.780 | -23.723 | -25.364 |
| | (1.6608) | (1.7081) | (1.7791) |
| January | -22.696 | -24.934 | -26.379 |
| | (1.1161) | (0.9722) | (1.1047) |
| February | -21.775 | -24.275 | -26.031 |
| | (2.0299) | (1.1219) | (0.9149) |

*SOURCE: Wample, Bob. "T-Rates Reports." IAREC. Prosser, Washington. 1987-1993.*
*NOTE: Standard deviations appear in parentheses.*

*TABLE 4. Assumed Average Yield by Variety and Year (Tons per Acre)*

| Variety | Average Yield by Year 1 | 2 | 3 | 4 | 5-20 |
|---|---|---|---|---|---|
| Cabernet Sauvignon | 0 | 0 | 2.5 | 4.5 | 5.5 |
| Chenin Blanc | 0 | 0 | 2.5 | 5 | 7.5 |
| White Riesling | 0 | 0 | 2.5 | 5 | 7 |

***TABLE 5. Ordinary Least-Squares Linear Regression Models of Yield Difference***

| Variety | Explanatory Variable | | Adjusted $R^2$ |
|---|---|---|---|
| | Constant | Percent Bud Kill | |
| Cabernet Sauvignon | -0.01956<br>(-0.21) | -0.02397<br>(-11.15) | .5548 |
| Chenin Blanc | -0.29450<br>(-1.26) | -0.02778<br>(-4.29) | .3319 |
| White Riesling | -0.13688<br>(-0.91) | -0.02264<br>(-4.70) | .2151 |

The size of the $R^2$ or coefficients of determination in Tables 2 and 5 can be explained by the cross-sectional nature of the data and the fact that the models were constructed to account for only winter damage from low temperatures. Cross-sectional data does not usually produce high $R^2$ because the data does not follow a smooth pattern or trend. There are several other factors during the growing season that also impact yields and are accounted for in the error terms of the equations.

The cost of production component of the model consisted of the costs incurred on an annual basis during both the establishment and full production phases of a vineyard (Tables 6 through 10). These yields and costs were taken from Washington State University Extension Bulletin 1588. Total costs represent all economic costs including the opportunities foregone by using the land for vineyard development. The costs are based on a 55-acre vineyard, with all new equipment, and a management fee of 7 percent of the average gross receipts. The costs directly related to yield such as harvesting were adjusted as the yields varied from the average based upon the percent primary bud damage and that impact on yield in the simulation. To calculate the net present value (NPV), internal rate of return (IRR), and payback period, all costs per acre were utilized except the interest on tractors, machinery, establishment costs, and interest charged on production input items during the year. As a result, the NPV, IRR, and payback period are for the investment in the vineyard (including machinery) and land. The total costs per acre used when average prices and yields (no bud damage) prevailed were:

| Year | Cabernet Sauvignon | Chenin Blanc | White Riesling |
|---|---|---|---|
| 1 | $2,058.90/acre | $2,052.03/acre | $1,934.65/acre |
| 2 | 2,656.72 | 2,558.76 | 2,532.47 |
| 3 | 1,835.29 | 1,790.51 | 1,764.25 |
| 4 | 1,729.90 | 1,715.12 | 1,688.88 |
| 5-19 | 1,789.90 | 1,865.12 | 1,808.88 |

These costs varied as bud damage, yields, and prices changed in the various simulations.

The basic information used to create the pricing component of the simulation model is reported in Table 11. The pricing component of the simulation model consists of an average price such as $874.67 per ton for Cabernet Sauvignon from 1991 to 1993. In the various scenarios, either the average price for a variety or a low or higher price level was utilized. The range of prices for Cabernet Sauvignon was from $796 to $953 per ton to stimulate market or price risk. This range was based upon the average price plus or minus one standard deviation calculated over the same time period. A price flexibility coefficient was used to adjust the price in each scenario for changes in yields caused by bud kill.

***TABLE 6. First-Year Revenues, Costs, and Profitability per Acre for Cabernet Sauvignon, Chenin Blanc, and White Riesling ($/AC)***

| | Variety | | |
|---|---|---|---|
| Activity | Cabernet Sauvignon | Chenin Blanc | White Riesling |
| Revenues: | | | |
| Production (tons) | 0.00 | 0.00 | 0.00 |
| Price ($/ton) | $ 874.67 | $ 395.33 | $ 379.00 |
| Total Revenues: | $ 0.00 | $ 0.00 | $ 0.00 |
| Costs: | | | |
| Variable Costs: | | | |
| Preharvest | $1,725.16 | $1,412.99 | $1,411.88 |
| Harvest | $ 0.00 | $ 0.00 | $ 0.00 |
| Postharvest | $ 0.00 | $ 0.00 | $ 0.00 |
| Management Fee | $ 308.00 | $ 210.00 | $ 183.75 |
| Total Variable Costs: | $1,725.47 | $1,622.99 | $1,595.63 |
| Fixed Costs: | | | |
| Machinery, Tractor, and Irrigation (Depreciation and Interest) | $ 254.47 | $ 254.47 | $ 254.47 |
| Land Taxes | $ 68.95 | $ 68.95 | $ 68.95 |
| Land Rent | $ 125.00 | $ 125.00 | $ 125.00 |
| Total Fixed Costs: | $ 448.42 | $ 448.42 | $ 448.42 |
| Total Costs | $2,173.58 | $2,071.42 | $2,044.05 |
| Profits (loss) | ($2,173.58) | ($2,071.42) | ($2,044.05) |

*TABLE 7. Second-Year Revenues, Costs, and Profitability per Acre for Cabernet Sauvignon, Chenin Blanc, and White Riesling ($/AC)*

| | Variety | | |
|---|---|---|---|
| Activity | Cabernet Sauvignon | Chenin Blanc | White Riesling |
| Revenues: | | | |
| Production (tons) | 0.00 | 0.00 | 0.00 |
| Price ($/ton) | $ 874.67 | $ 395.33 | $ 379.00 |
| Total Revenues: | $ 0.00 | $ 0.00 | $ 0.00 |
| Costs: | | | |
| Variable Costs: | | | |
| Preharvest | $2,356.50 | $2,044.33 | $2,043.21 |
| Harvest | $ 0.00 | $ 0.00 | $ 0.00 |
| Postharvest | $ 0.00 | $ 0.00 | $ 0.00 |
| Management Fee | $ 308.00 | $ 210.00 | $ 183.75 |
| Total Variable Costs: | $2,356.50 | $2,254.33 | $2,226.96 |
| Fixed Costs: | | | |
| Machinery, Tractor, and Irrigation (Depreciation and Interest) | $ 266.03 | $ 266.03 | $ 266.03 |
| Land Taxes | $ 68.95 | $ 68.95 | $ 68.95 |
| Land Rent | $ 125.00 | $ 125.00 | $ 125.00 |
| Interest on Establishment Costs | $ 184.75 | $ 176.07 | $ 173.74 |
| Total Fixed Costs: | $ 644.73 | $ 636.05 | $ 633.76 |
| Total Costs | $3,001.23 | $2,890.38 | $2,860.69 |
| Profits (loss) | ($3,001.23) | ($2,890.38) | ($2,860.69) |

**TABLE 8. Third-Year Revenues, Costs, and Profitability per Acre for Cabernet Sauvignon, Chenin Blanc, and White Riesling ($/AC)**

| | Variety | | |
|---|---|---|---|
| Activity | Cabernet Sauvignon | Chenin Blanc | White Riesling |
| Revenues: | | | |
| Production (tons) | 2.50 | 2.50 | 2.50 |
| Price ($/ton) | $ 874.67 | $ 395.33 | $ 379.00 |
| Total Revenues: | $2,186.67 | $ 988.32 | $ 947.50 |
| Costs: | | | |
| Variable Costs: | | | |
| Preharvest | $ 863.59 | $ 886.81 | $ 885.69 |
| Harvest | $ 150.00 | $ 150.00 | $ 150.00 |
| Postharvest | $ 142.49 | $ 142.50 | $ 142.50 |
| Management Fee | $ 308.00 | $ 210.00 | $ 183.75 |
| Total Variable Costs: | $1,464.08 | $1,389.31 | $1,361.94 |
| Fixed Costs: | | | |
| Machinery, Tractor, and Irrigation (Depreciation and Interest) | $ 279.88 | $ 320.16 | $ 320.16 |
| Land Taxes | $ 77.70 | $ 77.70 | $ 77.70 |
| Land Rent | $ 125.00 | $ 125.00 | $ 125.00 |
| Interest on Establishment Costs | $ 439.89 | $ 421.75 | $ 416.90 |
| Total Fixed Costs: | $ 922.44 | $ 944.61 | $ 939.76 |
| Total Costs | $2,386.53 | $2,333.92 | $2,301.70 |
| Profits (loss) | $ 199.86 | ($1,345.60) | ($1,354.20) |

**TABLE 9. Fourth-Year Revenues, Costs, and Profitability per Acre for Cabernet Sauvignon, Chenin Blanc, and White Riesling ($/AC)**

| | Variety | | |
|---|---|---|---|
| Activity | Cabernet Sauvignon | Chenin Blanc | White Riesling |
| Revenues: | | | |
| Production (tons) | 4.50 | 5.00 | 5.00 |
| Price ($/ton) | $ 874.67 | $ 395.33 | $ 379.00 |
| Total Revenues: | $3,936.02 | $1,976.65 | $1,895.00 |
| Costs: | | | |
| Variable Costs: | | | |
| Preharvest | $ 649.55 | $ 672.77 | $ 671.66 |
| Harvest | $ 270.00 | $ 300.00 | $ 300.00 |
| Postharvest | $ 142.50 | $ 142.50 | $ 142.49 |
| Management Fee | $ 308.00 | $ 210.00 | $ 183.75 |
| Total Variable Costs: | $1,370.05 | $1,325.27 | $1,297.90 |
| Fixed Costs: | | | |
| Machinery, Tractor, and Irrigation (Depreciation and Interest) | $ 247.55 | $ 287.83 | $ 287.87 |
| Land Taxes | $ 77.70 | $ 77.70 | $ 77.70 |
| Land Rent | $ 125.00 | $ 125.00 | $ 125.00 |
| Interest in Establishment Costs | $ 472.71 | $ 524.51 | $ 532.86 |
| Total Fixed Costs: | $ 922.96 | $1,015.04 | $1,023.39 |
| Total Costs | $2,293.01 | $2,340.31 | $2,321.30 |
| Profits (loss) | $1,643.01 | ($ 363.66) | ($ 426.30) |

***TABLE 10. Revenues, Costs, and Profitability per Acre for Cabernet Sauvignon, Chenin Blanc, and White Riesling, Years 5 through 19 ($/AC)***

| | Variety | | |
|---|---|---|---|
| Activity | Cabernet Sauvignon | Chenin Blanc | White Riesling |
| Revenues: | | | |
| Production (tons) | 5.50 | 7.50 | 7.00 |
| Price ($/ton) | $ 874.67 | $ 395.33 | $ 379.00 |
| Total Revenues: | $4,810.69 | $2,964.98 | $2,653.00 |
| Costs: | | | |
| Variable Costs: | | | |
| Preharvest | $ 649.55 | $ 672.77 | $ 671.66 |
| Harvest | $ 330.00 | $ 450.00 | $ 420.00 |
| Postharvest | $ 142.50 | $ 142.50 | $ 142.49 |
| Management Fee | $ 308.00 | $ 210.00 | $ 183.75 |
| Total Variable Costs: | $1,430.05 | $1,475.27 | $1,417.90 |
| Fixed Costs: | | | |
| Machinery, Tractor, and Irrigation (Depreciation and Interest) | $ 247.55 | $ 287.83 | $ 287.83 |
| Land Taxes | $ 77.70 | $ 77.70 | $ 77.70 |
| Land Rent | $ 125.00 | $ 125.00 | $ 125.00 |
| Interest on Establishment Costs | $ 415.65 | $ 611.70 | $ 656.08 |
| Total Fixed Costs: | $ 865.90 | $1,102.23 | $1,146.61 |
| Total Costs | $2,295.95 | $2,577.50 | $2,564.52 |
| Profits (loss) | $2,514.74 | $ 387.48 | $ 88.48 |

The price flexibility coefficient is an estimate of the percentage change in price given a percentage change in quantity. The price flexibility coefficient derived from single equation price prediction models was -0.3690 for Cabernet Sauvignon, -0.7322 for Chenin Blanc, and -1.1612 for White Riesling (Table 12).

The simulation model found the percentage change in quantity by utilizing the following formula:

$$\%\Delta Q = \frac{Q_2 - Q_1}{(Q_2 + Q_1)/2} * 100$$

where $\%\Delta Q$ = percentage change in quantity;
$Q_1$ = new yield; and
$Q$ = average yield.

This percentage change in quantity was assumed for the entire Washington industry and used in the simulation to adjust the price. While winter damage may vary from vineyard to vineyard, the simulation model used the predicted change in quantity as an average for the entire industry.

The price used was the average unless there was a change in yield. When a change in yield occurred, the price was adjusted by using two equations in a two-step process. The first equation was:

$$|\%\Delta P| = F * \%\Delta Q$$

where:
$|\%\Delta P|$ = absolute percentage change in price;
$F$ = price flexibility coefficient; and
$\%\Delta Q$ = percentage change in yield

***TABLE 11. Average Prices per Ton by Variety and Year***

| | Average Price per Ton by Year | | | |
|---|---|---|---|---|
| Variety | 1991 | 1992 | 1993 | Average |
| Cabernet Sauvignon | 960 | 858 | 806 | 874.67 (78.34) |
| Chenin Blanc | 412 | 388 | 386 | 395.33 (14.47) |
| White Riesling | 384 | 381 | 372 | 379.00 (6.25) |

***SOURCE: Washington State Statistical Service. Grape Report. 1993.***
***NOTE: Standard deviations appear in parentheses.***

*TABLE 12. Single Equation Price Dependent Demand Models*

| | Explanatory Variables | | | | Adjusted $R^2$ |
|---|---|---|---|---|---|
| Variety | Constant | Quantity | LogY | Dummy | |
| Cabernet Sauvignon | 1,149.41<br>(6.96) | -0.06465<br>(-2.91) | -401.655<br>(-2.93) | 129.767<br>(2.67 ) | .8524 |
| Chenin Blanc | 697.148<br>(5.91) | -0.09644<br>(-2.91) | | | .4830 |
| White Riesling | 829.995<br>(4.01) | -0.03477<br>(-2.59) | -132.25<br>(-1.13) | | .3712 |

***NOTE: Student's t-values appear in parentheses and the estimation technique was ordinary least-squares. These variables were:***

Quantity = quantity of the variety being analyzed;
LogY = log of the years; and
Dummy = where years 1989 through 1993 are coded one and 1985 through 1988 are coded zero.

Once the percentage change in price was calculated, then the new price was found by:

NP = %ΔP * P
where: NP= new price;
%ΔP = percentage change in price; and
P = average price.

By utilizing this equation, the simulation adjusted the price for a change in yield.

Once the costs were found, the net return (loss) for the year was determined by taking the price and yield calculated by the simulation and multiplying them together and then subtracting the total costs of the production. This was done for each year within a single 19-year simulation. The model for each scenario was run 2,000 times for years 1 through 19 in the life of a vineyard. The net returns results were stored for each of the 2,000 19-year simulations and the NPV, IRR, and payback period were calculated. The NPV, IRR, and payback period are based on all 19 years including the establishment years of 1 through 4.

# RESULTS

There were two broad categories of results from the computer simulation model: (1) bud kill rates and (2) average net returns and financial analysis. A total of six models were run for each variety. The six models consisted of 0, +1, and +2 standard deviations on the $T_{10}$ temperature means and -1, +1, and 0 standard deviations on the average prices. The standard deviations were calculated on historical data as reported in Table 11.

## Bud Kill Rates

Two bud kill results were analyzed. One for +1 standard deviation on the $T_{10}$ temperature and another for +2 standard deviations. Summary statistics of the simulations on bud kill rates are presented for 0 to 30 percent and 31 to 70 percent bud kill (Table 13). The totals for each of the three months are presented since each month was analyzed separately. Only the $T_{10}$ level was adjusted to reflect increased production risk. There were no occurrences in the simulation runs in which there was more than 70 percent bud kill and temperatures which reached the $T_{50}$ and $T_{90}$ levels.

A +1 standard deviation increase in the $T_{10}$ amounts to increasing the critical temperature for $T_{10}$ from -20.61°F to -18.63°F for the month of January for Cabernet Sauvignon. The +1 standard deviation on $T_{10}$ temperature mean rarely resulted in bud kill in December. In January, bud kill occurred, but only in the 0 to 30 percent range. February was the month where the major damage was observed with an increase in both the 0 to 30 percent and 31 to 70 percent categories. The total for all months indicate that bud kill occurs over the life of the vineyard 6.30 percent of the time for Cabernet Sauvignon, 8.55 percent of the time for Chenin Blanc, and 3.65 percent of the time for White Riesling.

When +2 standard deviations on the $T_{10}$ temperature mean was utilized, the bud kill increased as expected. This is equivalent to raising the January $T_{10}$ level to -16.64°F from the base of -20.61°F for Cabernet Sauvignon (see Table 3). In December, January, and February, an increase in the 0 to 30 percent bud kill was observed. Bud kill only occurred in the 31 to 70 percent range in February for all three varieties. No bud kill was observed in the 70 to 100 percent bud kill category. Over the life of the vineyard, Cabernet Sauvignon had a 9.15 percent bud kill, an increase in the percentage over +1 standard deviation by 2.85 percent. The increase for Chenin Blanc was 5.45 percent of the time over the life of a vineyard. The total percent of the time there was bud kill for Chenin Blanc was 14.0 percent with the higher $T_{10}$ temperature. White Riesling was the most hardy variety with bud kill only 3.65 and 4.05 percent of the time with one and two standard deviations added to the $T_{10}$ temperature.

***TABLE 13. Number of Times Buds Were Killed in 2,000 Simulation Runs for 19 Years by Variety, Month, Percent Bud Kill, and $T_{10}$ Temperature (number)***

| Percentage ofBuds Killed | Month | | |
|---|---|---|---|
| | December | January | February |
| $T_{10}$ + 1 Standard Deviation[a] | | —Cabernet Sauvignon— | |
| 0 - 30% | 0 | 54 | 44 |
| 31-70% | 0 | 0 | 28 |
| | | —Chenin Blanc— | |
| 0-30% | 1 | 75 | 43 |
| 31-70% | 0 | 0 | 52 |
| | | —White Riesling— | |
| 0-30% | 0 | 0 | 70 |
| 31-70% | 0 | 0 | 3 |
| $T_{10}$ + 2 Standard Deviation[a] | | —Cabernet Sauvignon— | |
| 0-30% | 19 | 81 | 55 |
| 31-70% | 0 | 0 | 28 |
| | | —Chenin Blanc— | |
| 0-30% | 31 | 135 | 59 |
| 31-70% | 0 | 0 | 55 |
| | | —White Riesling— | |
| 0-30% | 0 | 0 | 78 |
| 31-70% | 0 | 0 | 3 |

[a] ***See Table 2 for $T_{10}$ temperatures and standard deviations.***

## Net Returns, IRR, NPV, and Payback Period

Financial measures such as the internal rate of return (IRR), net present value (NPV), and payback period in years were conducted on the average net returns over the 19-year period. This was done for both +1 and +2 standard deviation on the $T_{10}$ temperature mean and -1, +1, and 0 standard deviation on average price for the varieties. The discount factor used was the same as the cost of capital at 8.5 percent.

To provide a basis upon which to compare the results presented in this section, the financial measure values when there is no bud kill and average prices for Cabernet Sauvignon were: (1) NPV, $15,816 per acre; (2) IRR, 38.27 percent; and (3) payback period, 4 years and 7 months. In the case of Chenin Blanc, the financial measure values when there is no bud kill and average prices were: (1) NPV, $1,807 per acre; (2) IRR, 13.46 percent; and (3) payback period, 8 years and 7 months. The measures for White Riesling under the same conditions were: (1) NPV, $184 per acre; (2) IRR, 9.76 percent; and (3) payback period, 10 years and 2 months.

When a +1 standard deviation on the $T_{10}$ temperature mean and -1, +1, and 0 standard deviations on prices was employed in the simulation model, Cabernet Sauvignon had the higher returns (Table 14). The IRR, which ranged from 34.74 to 39.31 percent, more than covered the current cost of capital, resulting in a profitable investment. The NPV ranged from $10,425 to $16,519 per acre for Cabernet Sauvignon. An investment is acceptable if the NPV is greater than 0. The investment payback period ranged from 4.65 to 5.39 years. This short payback period would not present any problem in obtaining regular commercial financing.

Chenin Blanc did not prove to be an acceptable investment. With +1 standard deviation on the $T_{10}$ temperature mean and +1 and 0 standard deviation on the price. The IRR ranged from 3.62 to 7.92 percent, the NPV was always negative, and the payback periods were from 11.22 to 14.57 years. This shows that Chenin Blanc would not be an acceptable investment under the assumptions and conditions used in the simulation model.

The simulation results for White Riesling were similar to Chenin Blanc. The IRR never covered the cost of capital, and NPV was always negative. The payback period took from 15.22 to 18.66 years. Under the assumed conditions, this variety would not be a good investment. In fact, it is doubtful if a commercial financing institution would lend money under the assumed conditions and results obtained for these two white varieties.

***TABLE 14. Net Present Value (NPV), Internal Rate of Return, Payback Period Under Various Production and Price Risk Scenarios by Variety***

| Financial Measure | +1 Standard Deviation on $T_{10}$ | | | +2 Standard Deviations on $T_{10}$ | | |
|---|---|---|---|---|---|---|
| | Mean Price | -1 Standard Deviation on Mean Price | +1 Standard Deviation on Mean Price | Mean Price | -1 Standard Deviation on Mean Price | +1 Standard Deviation on Mean Price |
| **—Cabernet Sauvignon—** | | | | | | |
| NPV($/acre) | 13,473 | 10,426 | 16,519 | 13.976 | 10,425 | 16,517 |
| IRR(%) | 34.74 | 29.89 | 39.31 | 34.79 | 29.89 | 39.30 |
| Payback Period (yrs.) | 4.95 | 5.39 | 4.65 | 4.96 | 5.39 | 4.65 |
| **—Chenin Blanc—** | | | | | | |
| NPV ($/acre) | -1,175.35 | -2,028 | -541 | -1,287 | -2,030 | -543.02 |
| IRR(%) | 5.88 | 3.63 | 7.92 | 5.87 | 3.62 | 7.91 |
| Payback Period (yrs.) | 12.63 | 14.57 | 11.25 | 12.64 | 14.57 | 11.26 |
| **—White Riesling—** | | | | | | |
| NPV($/acre) | -2,561 | -2,864 | -2,259 | -2,561 | -2,864 | -2,259 |
| IRR(%) | 1.41 | 0.23 | 2.52 | 1.41 | 0.23 | 2.52 |
| Payback Period (yrs.) | 17.04 | 18.66 | 15.72 | 17.04 | 18.66 | 15.72 |

When a +2 standard deviation on the $T_{10}$ temperature mean and 0, +1, and -1 standard deviations on average price were used, the financial results were the same or slightly worse than the results for the same simulation when +1 standard deviation on the $T_{10}$ temperature mean was employed (Table 14). This was expected because of the inherent specification of the simulation model, where a restricted supply caused by bud kill would increase the price of the grape varieties. This increased price is not great enough to compensate for the decreased yield; therefore, the net returns decrease. Since the +2 standard deviation on the $T_{10}$ temperature mean only increased bud kill in the 0 to 30 percent range, very little impact was seen on yield. Supply was hardly decreased when compared with the results of +1 standard deviation on $T_{10}$ temperature mean.

If the various scenarios are compared based upon price risk with the production risk held constant, the economic impacts are slightly larger. The NPV changes by about $3,000 per acre for Cabernet Sauvignon, $600 to $800 per acre for Chenin Blanc, and $300 per acre for White Riesling with a shift in prices by one standard deviation from the mean prices. In a similar fashion, the IRR and payback period changes are altered more with the price risk than the production risk.

Increased price risk had a larger financial impact than did the production risk increase. With a constant production risk ($T_{10}$ is constant), the reduction of the price from the average by one standard deviation resulted in the NPV for Cabernet Sauvignon decreasing $3,551 per acre or a 25.4 percent, the IRR dropped almost 4.9 percent, and the payback period increased about 4 months. In contrast, the increased production risk with prices remaining constant did not significantly impact the NPV, IRR, or payback period for any of the two varieties. Overall, the market or price risk has a greater impact than the production risk in terms of changing the financial results of a vineyard in Washington.

## CONCLUSIONS

Overall, the wine grape producer faces both production and marketing (price) risks. The reduction in NPV was greater for Cabernet Sauvignon than for Chenin Blanc and White Riesling was less. Cabernet Sauvignon was an acceptable investment from an economic perspective in terms of financial returns, while White Riesling and Chenin Blanc were not acceptable investments under the assumptions used in this analysis. The price or market risk is larger in magnitude than the production risk. However, even with the accounting of both types of risk, the investment in a vineyard can be profitable. While low wintertime temperatures might cause some individuals to not plant wine grapes in such a northern climate, the price/market risks of the wine grape industry are of even greater significance in impacting financial returns.

As stated in the introduction of this bulletin, it was assumed that the producer did not employ any risk management strategies. Some of the more common risk management tools available to the wine grape producer includes crop insurance, forward contracting, wind machines, and a mix of varieties since not all varieties are damaged to the same degree by low wintertime temperatures and do not have the same degree of price variation when the quantity supplied changes. A potential wine grape grower is encouraged to explore all of the risk management tools available in order to minimize the production and market risks faced in the production of wine grapes.

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