Effect of Revenue Insurance on Entry and Exit Decisions in Table Grape

Production: A Real Option Approach

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Abstract

This study determines the entry and exit thresholds of table grape farming with irreversible investment under uncertainty. Real option approach is adopted to consider the investment and management flexibility. Also revenue insurance is introduced to consider the effect of the risk management programs on the entry and exit thresholds. Results show that revenue insurance increases the entry and exit thresholds by 1% and 4%, respectively, thus discouraging new investment and current farming, as long as the revenue guarantee is less than the exit threshold. Revenue insurance increases the entry threshold by 3% and decreases the exit threshold by 13% as long as the revenue guarantee is greater than the exit threshold. In this case, revenue insurance discourages the investment and encourages the current farmer to stay in farming, further. However, the decrease in the subsidy rate results in the increase in both entry and exit thresholds. Thus, the premium subsidy levels should be carefully considered if the policy objective is to encourage growers to shift to higher-value crops.

Key words: real options, capital budgeting, investment analysis, crop insurance, table grapes

Introduction

Grapes are a high value crop that constitutes the largest perennial crop in the U.S., with bearing acreage increasing from almost 700,000 acres in 1980 to almost 950,000 acres in 2000 (Fruit and Tree Yearbook). Currently, California accounts for 90% of domestic production. However, table grapes can potentially be grown in several regions of the U.S. For example, initial field trials have demonstrated that table grapes can effectively be grown in some regions of Texas (Stein and McEachern). However, though table grapes can technically be grown, the timing and size of future cash flows are key factors that farmers consider when deciding whether to invest in establishing a table grape vineyard.

Passage of the Agricultural Risk Protection Act (ARPA) in 2000 greatly expanded the availability of crop insurance for farmers. Not only have premium subsidies increased, but also the types of policies available and the crops that can be insured. As a result, when evaluating whether to invest in establishing a vineyard, the risk averse farmer should also include crop insurance in the analysis because crop insurance changes the revenue distribution, and consequently, affect the riskiness of future cash flows. Currently, a variety of policies are available that provide insurance coverage for farmers growing grapes. For example, grower yield certification (GYC) and GYC-Span are policies available in various states that provide yield insurance for grape growers, while adjusted gross revenue (AGR) and the recently developed AGR-Lite provide revenue insurance for grape growers in several states. These or similar policies are also available for farmers growing other perennial crops. Furthermore, the geographic availability of these and similar policies is likely to continue to expand as a result of the ARPA mandate.

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Given these policy developments, it seems important to incorporate crop insurance into the economic analysis of the farmer's investment decision when evaluating perennial crops such as grapes.

Traditionally, the net present value (NPV) has been widely adopted as a capital budgeting method to identify valuable investments. However, the NPV approach has been criticized because it only considers the current decision, not the management flexibility to invest at later date (Myers). By waiting, the investor or manager may gather more valuable information and thus stand a better position for decision-making. As an alternative to NPV, the concept of real options has been used to overcome the shortcomings of traditional NPV (Trigeorgis). The real option approach applies the financial option concept to the investment in real assets when the decision is made under uncertainty (Dixit (1989) and Dixit and Pindyck). The approach accounts for the opportunity to exercise an option to undertake the investment over a given period of time. For example, if two periods are exclusively available for the investment, the investor can make a decision now or next year. If the investor waits until next year, he invests only when the uncertainty has been resolved and the market condition is favorable. Otherwise the investor chooses not to invest, avoiding the bad outcome and limiting losses. Like financial options, a potential investor has the right, but not the obligation, to sell or buy the underlying assets at a pre-specified price for a given period. Waiting or flexibility in timing the investment may eliminate the unfavorable situation, thus producing higher project value from the investment. While traditional NPV allows only now or never decisions in investment, the real option approach provides more flexibility and valuable information in investment (or disinvestments) and management decision-making. We

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adopt a real option approach as the theoretical decision criterion for the investment in a vineyard. We consider an industry-level perspective in order to draw policy-relevant conclusions about crop insurance programs and their potential impact on investment in agriculture.

In a competitive industry, the value of the option to wait for any one farm is affected by the fact that many farmers enter the industry whenever its value is positive (Leahy). Given an inverse demand function with negative slope, new entrants constitute an increase in supply, resulting in lower market price and thus decreased marginal benefit from investment.

Many previous studies have utilized entry and exit models. Brennan and Schwartz introduced the entry and exit model with several management strategies. Dixit (1989) showed only the entry and exit decision model and provided some analytical results. Leahy showed that the entry and exit model resulted in the same thresholds for both the myopic firm and competitive equilibrium. Dixit and Pindyck provided the entry and exit model with both a single firm having monopoly to invest and competitive equilibrium in their textbook. Dixit (1991) developed irreversible investment model under demand uncertainty with price ceiling in a competitive industry and Dixit and Pindyck provided the entry and exit model with price ceiling and price floor in a competitive industry. All these studies found that options on investment timing are different in an industry perspective compared with an individual investor, and confirmed the importance of taking uncertainty into account in investment modeling.

Recent real option studies in the agricultural economics literature include the entry-exit decision (Price and Wetzstein; Isik et al), the replacement decision of

equipment (Hyde, Stokes, and Engel), the sequential investment decision in crop management (Isik, Khanna, and Winter-Nelson), and technology adoption (Purvis et al). Also Salin studied the impact of food safety risks on capital investment. However, no studies consider the risk management strategy, especially crop insurance, in the investment decision.

This paper determines the investment (entry) and disinvestments (exit) thresholds for table grape farming using a real option approach when crop insurance is available to the risk-averse farmer in California. By calculating the entry and exit threshold with crop insurance and without crop insurance, we determine the effect of crop insurance on investment decisions in table grape farming. This study makes a contribution in that it extends the body of real option studies to see how crop insurance modifies the investment decision.

Model

Model Assumptions

We analyze the entry and exit model under the assumption of a competitive industry. An investment or capital budgeting is a long-term and strategic decision in farm level. In a long-term perspective, many farmers can join or leave grape farming according to market conditions. They act competitively so that abnormal project value disappears. That is, in a competitive industry, positive project value induces more inactive farmers and negative project value leads to the active operator leaving the business, resulting in dynamic equilibrium in the long run. Thus, when making investment decision, the farmer needs to consider the potential entrance of competitive

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farmers. We assume many grape farmers who are price takers so that each farm's investment decision doesn't affect market price. We also assume homogeneous products to eliminate price differentiation for the analysis.

Uncertainty in the competitive industry could be farm specific and industry-wide (or aggregate uncertainty), where the former can be explained by the uncertainty of management skill (or technology) and commodity specific demand and the latter can be explained by aggregate demand uncertainty or a widespread disaster in production. In this paper, we assume industry-wide uncertainty because most of the uncertainties in agriculture are caused by market conditions or production dependency on nature. In a competitive industry, price is an endogenous variable determined by the demand and production relationships, where both are assumed to be uncertain in this study. Because price is a decreasing function of demand in aggregate level, demand uncertainty results in price that moves stochastically. Yield also changes stochastically because of production uncertainty. Yield and price are correlated, which is included in the specification of price and yield stochastic processes in the next section.

In the model, the investment costs are assumed to be partially reversible, which results in salvage values. On the other hand, the exit from the farming entails the costs, such as the elimination cost of trees or restoring cost of the land. In this study, we assume that the exit costs totally counteract the salvage values so that both factors cane be eliminated in the model. Once the farmer gets out of farming, he should spend same amount of investment costs to enter the farming again. The variable cost is assumed to be relatively constant and thus the risk free rate must be used to discount it.

To solve the model, we can use dynamic programming approach or contingent claim analysis that lead to the same solutions (Dixit and Pindyck). However, the latter requires an assumption that uncertainty of an asset be replicated by spanning existing assets so that the risk free rate can be used. Otherwise, dynamic programming approach can be used to maximize the present value of cash flow. This approach requires the assumption of risk preferences or discount rates. In this study, we follow the dynamic programming approach because the agricultural uncertainty cannot be easily spanned. Thus, we use the risk-adjusted discount rate to discount uncertain revenue flow.

Entry and Exit Model with No Revenue Insurance

To obtain the stochastic evolution of the value of project over time that affects the investment decision, we need stochastic processes of relevant variables. We assume price and yield are stochastic variables that follow geometric Brownian motion[1] (Turvey; Price and Wetzstein). When price and yield follow geometric Brownian motions, revenue also follows a geometric Brownian motion:

(1) $dR = \alpha_R R dt + \sigma_R R dZ_R,$

where α is the drift parameter, σ is the volatility parameter, dt is a small time increment, and dZ is the increment of the standard Brownian motion (or Wiener process).

Given the stochastic process of equation (1), the option value of an inactive farm that has the opportunity to enter farming, and the value of an active farm that has the option to leave the industry are determined simultaneously. In a competitive industry, the entry and exit thresholds play roles as the upper and lower reflecting barriers that are the

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[1] The origins of Brownian motion processes are in physics, specifically the characteristics of a heavy particle being bombarded by lighter particles (Salin).

equilibrium revenues for inactive farmers and active farmers, respectively (Leahy). Dixit

and Pindyck provided the simultaneous equations for the solution of thresholds with price

uncertainty under dynamic equilibrium in a competitive industry. With some

mathematical derivations, the simultaneous equations are given as

(2) $\qquad (B_1 - A_1)R_H^{\beta_1} + (B_2 - A_2)R_H^{\beta_2} + \dfrac{R_H}{\delta} - \dfrac{C}{r} = I$

(3) $\qquad \beta_1(B_1 - A_1)R_H^{\beta_1-1} + \beta_2(B_2 - A_2)R_H^{\beta_2-1} + \dfrac{1}{\delta} = 0$

(4) $\qquad (B_1 - A_1)R_L^{\beta_1} + (B_2 - A_2)R_L^{\beta_2} + \dfrac{R_L}{\delta} - \dfrac{C}{r} = 0$

(5) $\qquad \beta_1(B_1 - A_1)R_H^{\beta_1-1} + \beta_2(B_2 - A_2)R_H^{\beta_2-1} + \dfrac{1}{\delta} = 0,$

where β_i are the roots of the fundamental quadratic equation, which will be obtained

following the procedures of Dixit and Pindyck. A_i and B_i are constants to be determined,

where $A_1 R^{\beta_1}$ is the value of the option to enter, $A_2 R^{\beta_2}$ is the increase in value from lower

reflecting barrier, $B_1 R^{\beta_1}$ is the decrease in value from upper reflecting barrier, and

$B_2 R^{\beta_2}$ is the value of the option to exit. C is the variable cost, I is the investment cost, r is

the risk free rate of return, and δ is the rate of return shortfall that is the risk-adjusted rate

of return ρ adjusted by the drift rate α, such as $\delta = \rho - \alpha$. δ is commonly assumed to be

greater than zero ($\rho > \alpha$) otherwise no optimum exists and waiting is the best decision.

Equation (2) and equation (4) are value-matching conditions that require the value of

waiting to equal the value of investing (or abandoning) at the entry (or exit) threshold.

Equation (3) and equation (5) are smooth-pasting conditions that require the same slopes

of the value of waiting and the value of investing (or abandoning) at each threshold level.

The last two terms of equation (2) and equation (4) denote the expected net present values of an infinite annuity of profit evaluated with the entry and exit threshold levels in case of no upper (lower) reflecting barriers, where revenue flow is discounted by the rate of return shortfall and constant cost is discounted by risk free rate. By setting (B_1-A_1) and (B_2-A_2) as K_1 and K_2, we can solve the simultaneous equation with four unknowns, K_1, K_2, R_H, and R_L. These equations are highly non-linear in the thresholds, R_H and R_L, thus the solution to the equations requires a numerical procedure. In the model, optimal entry and exit thresholds are equilibrium revenue levels with upper and lower reflecting barriers, respectively, which result in zero option value of waiting (A_1=A_2=0).

The entry and exit thresholds with the real options are compared with those with the NPV approach. The entry threshold with the NPV approach is determined by the long-run average cost ($\frac{\delta C}{r} + \delta I$). The exit threshold with the NPV approach is obtained by short-run average variable cost ($\frac{\delta C}{r}$).

Entry and Exit Model with Revenue Insurance

Revenue insurance guarantees revenue floor ($\underline{R}$) by requiring a constant premium and thus increasing a variable cost. Given the revenue flow R, if the revenue guarantee (or revenue floor) $\underline{R}$ is less than the exit threshold R_L, then the revenue insurance doesn't affect the entry and exit thresholds because, when the revenue is less than the exit threshold, the farmer gets out of the farming. If the revenue guarantee is binding, that is, if it is greater than the exit threshold, then revenue insurance affects the exit decision as well as the entry decision. Revenue guarantee induces more inactive farmers to invest and more active farmers to stay in farming, resulting in the increase in the supply and

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thus the decrease in both the entry and exit thresholds. On the other hand, revenue insurance requires that an active producer pay the insurance premium, which reduces the net revenue flow and decreases the attractiveness of entry, so that we need to consider the trade off between the revenue guarantee and insurance premium.

The model can be separated into two cases. The first case is when the revenue guarantee is greater than the exit threshold but less than the variable cost, ($R_L \leq \underline{R} \leq \frac{\delta}{r}C$). The second case is when the revenue guarantee is greater than the variable cost but less than the long run average cost ($\frac{\delta}{r}C \leq \underline{R} \leq \frac{\delta}{r}C + \delta I$). In this study, we focus on the first case because it is rare for the revenue guarantee from crop insurance to exceed the variable cost. However, even though the guaranteed level is less then the variable cost, two cases must be considered. The first case is when the revenue is greater than the exit threshold but less than the revenue guarantee, $R_L \leq R \leq \underline{R}$. The second case is when the revenue is greater than the revenue guarantee but less than the variable cost, $\underline{R} \leq R \leq \frac{\delta}{r}C$.

Let's consider the first case, $R_L \leq R \leq \underline{R}$. If the revenue is greater than the exit threshold and less than the revenue guarantee, then the project value is

(6) $\quad V(R) = \frac{\underline{R}}{r} - \frac{(C + \pi)}{r} + A_1 R^{\beta_1} + A_2 R^{\beta_2}$,

where π is the insurance premium, which may include a subsidy from the government, and A_1 and A_2 are the constants to be determined. The first two terms in equation (6) are the expected present value of an infinite annuity of profit with revenue insurance, where the revenue has the lower boundary caused by insurance indemnity payment and thus

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discounted by the risk free rate. The other two terms are the values adjusted by the upper

reflecting barrier and the value of the option to exit given revenue guarantee.

Additionally we have the value matching condition $V(R_L)=0$ and smooth-pasting

condition $V'(R_L)=0$ that were explained earlier. This value matching condition is

obtained by setting the option value of waiting to be zero in a competitive market.

If the revenue is greater than the revenue guarantee but less than the variable cost,

$\underline{R} \le R \le \dfrac{\delta}{r}C$, then the project value is

$$(7) \qquad V(R) = \frac{R}{\delta} - \frac{(C+\pi)}{r} + B_1 R^{\beta_1} + B_2 R^{\beta_2} ,$$

where B_1 and B_2 are the constants to be determined. In equation (7), the expected present

value of an annuity of revenue is discounted by the rate of return shortfall, where the

revenue is not bounded from the floor, but the cost is discounted by risk free rate. The

other two terms are the values adjusted by upper reflecting barrier and the value of the

option to exit given revenue guarantee. The value matching and smooth-pasting

conditions are $V(R_H) = I$ and $V'(R_H) = 0$, respectively. Assuming the value function $V(R)$

is continuously differentiable around $\underline{R}$, we get the following equations by equating two

equations (6) and (7), and differentiating it.

$$(8) \qquad \frac{\underline{R}}{r} - \frac{\underline{R}}{\delta} + (A_1 - B_1)\underline{R}^{\beta_1} + (A_2 - B_2)\underline{R}^{\beta_2} = 0$$

$$(9) \qquad -\frac{1}{\delta} + \beta_1(A_1 - B_1)\underline{R}^{\beta_1-1} + \beta_2(A_2 - B_2)\underline{R}^{\beta_2-1} = 0 .$$

Additionally, from the value matching and smooth-pasting conditions, we have four more

equations to solve.

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(10) $\dfrac{R}{r} - \dfrac{(C+\pi)}{r} + A_1 R_L^{\beta_1} + A_2 R_L^{\beta_2} = 0$

(11) $\beta_1 A_1 R_L^{\beta_1-1} + \beta_2 A_2 R_L^{\beta_2-1} = 0$

(12) $\dfrac{R_H}{\delta} - \dfrac{(C+\pi)}{r} + B_1 R_H^{\beta_1} + B_2 R_H^{\beta_2} = I$

(13) $\dfrac{1}{\delta} + \beta_1 B_1 R_H^{\beta_1-1} + \beta_2 B_2 R_H^{\beta_2-1} = 0$

Now we have six simultaneous equations from (8) to (13) and six unknowns that include

four constants, A_1, A_2, B_1, and B_2, and two thresholds, R_H and R_L. These equations also

are highly non-linear in the thresholds, R_H and R_L, thus the solution to the equations

requires a numerical procedure.

Data

Data without Revenue Insurance

California data on table grapes are used to calculate the parameters needed, where

the price and yield series are statewide, provided by California Agricultural Statistics

Service. The trend and variance of yield and price series are calculated from the

logarithm of the data (table 1). Both the yield and price show positive trends, 0.003 and

0.033, respectively. The yield variance is 0.02 and the price variance is 0.04. The

correlation between the yield and price is –0.58. The drift rate (trend) and volatility rate

of revenue are 0.02 and 0.167, where the trend is adjusted from 0.049 because it is too

high to last for infinity in a competitive market. Instead, we do sensitivity analysis.

The economic life of a table grape vineyard is twenty-five years and grape

harvesting begins in the fourth year. However, the farming operation is an ongoing

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business, thus following the subsequent farming operation at the end of the economic life. This leads to an infinite horizon model (Price and Wetzstein). The investment cost includes the initial investment cost and three years of operating cost for vineyard establishment. Initial investment cost is $11,921 per acre and the first three years of operating cost is $6,717 per acre, thus making the total investment cost $18,638 per acre (University of California-Cooperative Extension). The operating cost is $5,559 per acre, per year.

The risk-adjusted rate is assumed as 0.08 and the risk free rate is assumed as 0.07, comparable to Price and Wetzstein and Isik. Then the rate of return shortfall defined by the difference between the risk-adjusted rate and the drift rate of revenue is 0.06. The positive root of the fundamental quadratic equation, β_1, is 2.186 and the negative root of fundamental quadratic equation, β_2, is –2.614.

Data with Revenue Insurance

Until now, only yield insurance is available for table grapes in California. However, adjusted gross revenue (AGR) and the recently developed AGR-Lite provide revenue insurance for grape growers in several states. As mentioned, passage of the ARPA in 2000 greatly expanded the regions and the types of policies and crops available so that the introduction of revenue insurance is highly possible. Thus, we examine the effect of revenue insurance to consider the potential effect of implementing a new program in table grape in California.

Revenue insurance provides a revenue coverage level ranging from 50% to 75% by 5% increments of expected revenue, and a producer premium rate ranging from 33%

to 45% of the expected indemnity, respectively. For each coverage level, a price election factor ranges from 50% to 100%. 60% and 75% coverage levels of approved revenue with price election factor of 100% are chosen for the study, resulting in the producer premium rate of 36% and 45%, respectively (table 1). Thompson seedless grape in San Joaquin of California in 2002 is used to calculate the producer premium. The expected revenue is $7,000, thus the guaranteed revenues with coverage levels of 60% and 75% are $4,200 and $5,250, respectively (California Cooperative Extension). The base premium rates are assumed 6.3% for 65% coverage level and 9.4% for 75% coverage level based on GYC insurance, resulting in the premium of $95 and $222, respectively (USDA-RMA). New operating costs are $5,654 for 60% coverage level and $5,781 for 75% coverage level (table 1).

Result

The entry and exit thresholds of the NPV based on the Marshallian long run average cost and average variable cost are $5,883 and $4,765, respectively (table 2). Given the parameters, the simultaneous equations from equation (2) to equation (5) produce the entry and exit thresholds with the real option, where the entry threshold is $10,390 and the exit threshold is $4,371. Compared with the values of traditional NPV, the entry threshold with real option approach is higher than that of the traditional NPV and the exit threshold with real option is lower than that of the traditional NPV, and these results support the literature in finding a significant effect of accounting for uncertainty in the investment decision. The revenue that would stimulate entry is almost double the trigger level of revenue under traditional NPV analysis. The effect of real options on exit

is not nearly as dramatic, largely because in this framework it has been assumed that there is no sunk cost associated with exit.

As the variable cost increases, both the entry and exit thresholds increase. According to the increase in variable cost from $5,559 to $6,059, the entry threshold increases from $10,390 to $11,100 and the exit threshold increases from $4,371 to $4,804. Thus the higher the variable cost, the less the investment in table grape farming and the faster the exit from table grape farming.

As the investment cost increases, the entry threshold increases but the exit threshold decreases. The entry threshold is $10,640 and the exit threshold is $4,328 when the investment cost increases from $18,683 to $20,683. It widens the inaction gap defined as the difference between the entry threshold and the exit threshold, thus inducing less investment and less departure from farming operation.

As the risk-adjusted rate of interest increases, both the entry and exit thresholds increase. When the risk-adjusted rate increases from 0.08 to 0.09, the entry threshold increases from $10,390 to $11,550 and the exit threshold increases from $4,371 to $5,010. Thus the increase in the risk-adjusted rate induces less investment of the inactive farmer and more active producers leaving from table grape farming. This is because the higher discount factor decreases the expected present value of revenue.

Also, as the drift rate increases, both the entry and exit thresholds decrease. When the drift rate of revenue increases from 0.02 to 0.03, the entry threshold decreases from $10,390 to $10,140 and the exit threshold decreases from $4,371 to $4,221. Thus the higher the drift rate, the higher the investment in table grape farming and the slower the exit from table grape farming. When the future expectation is good enough, the

farmer would tend to stay in farming and it requires a low observed revenue to trigger exit.

As the volatility increases, the entry threshold increases and the exit threshold decreases. When it increases from 0.167 to 0.219, the entry threshold increases from $10,390 to $10,890 and the exit threshold decreases from $4,371 to $4,241. This confirms the usual result that uncertainty increases the option value for waiting. It widens the inaction gap, thus inducing less investment and less leaving in table grape farming.

The effect of revenue insurance on the entry and exit threshold

Revenue insurance increases the variable cost, and depending on the premium relative to risk reduction, increases both the entry and exit thresholds. It discourages the investment and farming operation for the inactive and active farmer, respectively. On the other hand, revenue insurance guarantees a minimum level of revenue and thus decreases both the entry and exit thresholds through the dampening of volatility on the stochastic process of revenue. This risk-reduction effect tends to encourage both the investment and continuation of farming operation. The net effect of revenue insurance on the entry and exit thresholds depends on the exit threshold and the relative magnitude of the indemnity and insurance premium.

The entry and exit thresholds with 60% coverage level are $10,520 and $4,536, respectively, due to the increased variable costs (table 3). However, the revenue guarantee of $4,200 is less than the exit threshold, $4,536, thus there is no effect on the entry and exit thresholds. Revenue insurance with 60% coverage level increases the

entry threshold by 1% and the exit threshold by 4%, resulting in the discouragement of the investment and current farming operation.

The entry and exit thresholds with 75% coverage level are $10,710 and $4,563, respectively, when the increased insurance premium is added in variable cost. However, the revenue guarantee of $5,250 is greater than the exit threshold, $4,563, thus affecting both the entry and exit thresholds. Thus new entry and exit thresholds with 75% coverage level are $10,660 and $3,813, respectively. Revenue insurance with 75% coverage level increases the entry threshold by 3% and decreases the exit threshold by 13%, resulting in the discouragement of the investment and the encouragement of the current farming operation.

Results show that the entry threshold with revenue insurance is higher than with no revenue insurance and the trigger level for entry increases according to the insurance coverage level. So revenue insurance discourages the initial investment decision. And also the higher the insurance coverage level, the higher the discouragement in investment decision regardless of the relationship between revenue guarantee and the exit threshold. This result explains that cost effect dominates revenue effect when the farmer makes an investment decision with crop insurance given investment flexibility. An implication of this finding is that premium subsidy levels should be carefully considered if the policy objective is to encourage growers to shift to higher-value crops that may have more risky future returns than the major program crops.

60% coverage level produces the higher exit threshold and 75% coverage level produces the lower exit threshold compared with no revenue insurance, respectively. The big difference of these two coverage levels basically results from the revenue guarantee,

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where 60% coverage level has the lower revenue guarantee and 75% coverage level has the higher revenue guarantee than the exit threshold without revenue insurance. As long as the revenue guarantee is less than the exit threshold, the revenue insurance only increases the variable cost, thus increasing the exit threshold. It discourages the active farmer to stay in farming. However, revenue effect dominates the cost effect provided the revenue guarantee is greater than the exit threshold, thus encouraging the current farmer to stay in farming, further.

Table 3 shows the effect of the change in insurance premium rate on the entry and exit decision. For example, as the insurance premium rate with 60% coverage level increases from 6.3% to 30%, the entry threshold increases from $10,520 to $11,030 and the exit threshold increases from $4,536 to $4,882. In both coverage levels, as the insurance premium increases, the entry and exit thresholds increase. Thus the higher insurance premium discourages the investment and current farming operation.

On the other hand, table 3 shows the effect of insurance premium subsidy on the entry and exit thresholds. As the insurance premium subsidy increases, the premium rate to be paid by the farmer decreases. Thus the insurance premium subsidy decreases the entry and exit thresholds, which imply the encouragement of the investment and current farming operation.

Conclusion

This study determines the entry and exit thresholds of table grape farming with irreversible investment under uncertainty in California. The real option approach is adopted to consider the investment and management flexibility. Also revenue insurance

is introduced to consider the effect of the risk management programs on the entry and exit thresholds.

The results show that the entry threshold with real option approach is higher than that with the traditional NPV approach and the exit threshold with real option approach is lower than that with the traditional NPV approach. This is a standard result in the real options literature. From the perspective of an application to table grape production, uncertainty in future returns in this industry tends to discourage investment by the inactive farmer and encourages the active farmer to stay in farming.

Revenue insurance increases the entry and exit thresholds compared with no revenue insurance, provided the revenue guarantee is less than the exit threshold. In this case, revenue insurance discourages both the investment and the current farming operation. Revenue insurance increases the entry threshold and decreases the exit threshold as long as the revenue guarantee is greater than the exit threshold. In this case, revenue insurance discourages the investment and encourages the active farmer to stay in farming.

Insurance premium subsidy decreases the variable costs, thus decreasing both the entry and exit thresholds. So the insurance premium subsidy encourages the investment and current farming operation.

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Table 1. Parameters used for table grape farming without crop insurance in Texas.

Parameters	Parameter Values
Investment Cost ($/acre)	18,638
Variable Cost ($/acre)	
No Insurance	5,559
60% Coverage Insurance	5,654
75% Coverage Insurance	5,781
Expected Revenue ($/acre)	7,000
Guaranteed Revenue ($/acre)	
60% Coverage Insurance	4,200
75% Coverage Insurance	5,250
Insurance Premium Rate (%)*	
60% Coverage Insurance	6.3
75% Coverage Insurance	9.4
Producer Premium Rate (%)*	
60% Coverage Insurance	36.0
75% Coverage Insurance	45.0
Drift Rate	
Yield	0.001
Price	0.054
Revenue	0.002
Volatility (variance) Rate	
Yield	0.020
Price	0.040
Revenue	0.028
Correlation	-0.58
Beta	
Positive	2.186
Negative	-2.614
Risk Adjusted Rate	0.08
Risk Free Rate	0.07
Rate of Return Shortfall	0.06

* includes the insurance premium subsidy

Table 2. The change in the entry and exit thresholds by parameters

	Parameters	NPV ($)		Real Options ($)	
		Entry	Exit	Entry	Exit
Variable Cost	5,059	5,455	4,336	9,666	3,943
	5,559	5,883	4,765	10,390	4,371
	6,059	6,312	5,193	11,100	4,804
Investment Cost	16,638	5,763	4,765	10,120	4,419
	18,638	5,883	4,765	10,390	4,371
	20,638	6,003	4,765	10,640	4,328
Risk Adjusted Rate	0.07	4,903	3,971	9,209	3,741
	0.08	5,883	4,765	10,390	4,371
	0.09	6,864	5,559	11,550	5,010
Drift Rate	0.01	6,864	5,559	10,650	4,519
	0.02	5,883	4,765	10,390	4,371
	0.03	4,903	3,971	10,140	4,221
Volatility Rate	0.018	5,883	4,765	9,775	4,539
	0.028	5,883	4,765	10,390	4,371
	0.038	5,883	4,765	10,890	4,241

Table 3. The entry and exit thresholds by insurance premium rate

| | Premium Rate (%) | NPV ($) | | Real Option ($) | | | |
		Entry	Exit	Entry	(%)	Exit	(%)
No Insurance		5,883	4,765	10,390		4,371	
Insurance							
60% Coverage Level	6.3	5,965	4,846	10,520	(1.01)	4,536	(1.04)
	20	6,142	5,024	10,810	(1.04)	4,742	(1.08)
	30	6,272	5,154	11,030	(1.06)	4,882	(1.12)
75% Coverage Level	9.4	6,073	4,955	10,660	(1.03)	3,813	(0.87)
	20	6,289	5,170	11,050	(1.06)	4,391	(1.00)
	30	6,491	5,373	11,390	(1.10)	4,812	(1.10)

( ): Ratio of the entry and exit thresholds calculated based on no insurance