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What Is Making Vineyard Investment in Northwest Victoria, Australia, Slow to Adjust?*

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Abstract

This paper reports a use of the real-options valuation methodology to analyze wine grape vineyard investment under price and yield uncertainty. Threshold annual rates of revenue per hectare to trigger entry and exit, respectively, were calculated for three different sizes of wine grape vineyards in northwest Victoria, Australia. The modeling identified lower exit and higher entry triggers than would be indicated by a conventional approach that ignores the uncertainty underpinning adaptive investment decisions. Between these triggers is a relatively wide gap of estimated indeterminacy in vineyard investment that highlights the intertwined influence of numerous economic factors—cost structure, economies of scale, market volatility, transaction costs, and sunk and salvaged asset valuation. Drawing on these determinants of vineyard investment and disinvestment, the paper discusses the role of investment incentives in affecting industry transformation and the scope for policy intervention to assist structural adjustment of the wine grape sector. (JEL Classification: C61, G11, I25, Q12)

Keywords: Australia, entry and exit, northwest Victoria, real options, wine grape.

I. Introduction

The history of wine grape production in northwest Victoria, Australia, goes back to the late nineteenth century. More recently, the rise in wine grape prices during the 1990s attracted an influx of growers to the industry and, consequently, led to a rapid expansion of the industry in the region.

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Since the early 2000s, the regional wine grape sector has been experiencing economic difficulties. Numerous factors have contributed to persistent declines in vineyard revenue, including depressed world prices of wine, long and severe droughts in the region followed by damaging floods in 2010, high input costs relative to those in competing countries and the appreciation of the Australian dollar. At the moment many wine grape growers are earning insufficient income to pay for all operating costs of production and, hence, are not recovering overheads or earning positive returns to capital. Some growers are still harvesting because grape prices, while low, exceed the costs of harvesting. Despite such profit pressures, restructuring in the wine grape sector has been slow.

From a historical perspective, the problem with sectoral adjustment is not new. Osmond and Anderson's (1998) review of the development of the Australian wine industry since the mid-1800s makes it clear that the current downturn is just another episode of the boom–bust cycles that characterize the fluctuating fortunes of wine grape growers. In particular, all the booms started with a surge of new plantings and finished with a plateau in vineyard area and output growth. The stimuli for booms varied, ranging from domestic demand growth, export demand growth to policy inducement, innovation, and consumer taste change. Yet all such gyrations basically reflected the reactions and consequences of investment under uncertainty.

It is important to distinguish causes from symptoms of the adjustment problem. Particular symptoms could emerge to overshadow the fundamental nature of boom–bust cycles. For example, a general lack of confidence in the future viability of wine grape farming results in a poor prospect for family succession, which may be mistaken as a specific, situational problem relating to the aging of vineyard owners.

This study aims to provide an economic explanation for the sluggish adjustment of the wine grape sector. It adopts a real-options modeling approach to explicitly take into account the impact of cost structures and revenue uncertainties on investment. We believe that this approach, by using a rigorous investment framework, would bring a better understanding of the re-emerging problem relating to adjustment rigidity and its consequence of inefficient, unprofitable production at times.

Wine grape is a perennial crop; its production is characterized by relatively high orchard establishment costs, and uncertain yields and prices for particular grape varieties. It takes two to three years for vines to produce fruit, and additional years thereafter to reach their highest production potential. The stochastic nature of grape price and yield changes has important implications for investment decisions. While current vineyard revenues may be insufficient to pay off variable production costs, it could still be rational for growers to continue producing as the seasonal revenue may rise in the future. Exiting the current investment would risk forsaking potentially high profits in the future and incur losses of part or all of the initial investment.

In this paper, we show that an economic analysis of investment, if ignoring the characteristics of irreversibility and uncertainty, could underestimate the economic value of waiting and provide misleading evidence for guiding industry policy to facilitate structural adjustment. In Section II, we present an overview of various investment theories and practices. In Section III, we specify a real-options model suitable for analyzing investment in wine grape production. In Section IV, we discuss the data sources used for modeling and their limitations. In Section V, we present and discuss baseline results. In Section VI, we present sensitivity tests for key modeling results on a selection of vineyard characteristics. Section VII concludes the paper with a discussion of lessons for policy development.

II. Investment Theories and Practices

There is a vast economic literature on investment behavior that seeks to explain key considerations of individual firms when deciding whether to enter or exit particular markets. Understanding the relative strengths and limitations of such investment theories is essential for selecting a suitable approach to solve the problem at hand.

According to the Marshall's theory (Marshall, 1920), firms exit the industry whenever output price falls below average variable cost (i.e., operating profit is negative) and enter when output price is above long-run average cost (i.e., operating profit exceeds the economic cost of capital). Jorgensen (1963) criticized this theory on the grounds that its focus on current profit is too static and narrow.

Jorgensen (1963) argued that the calculus for investment decision should include expected profit flows over time. Under Jorgensen's neoclassical perspective, firms exit when staying in the industry would not deliver a positive net present value (NPV) of current and future cash flows. Discounted cash flow (DCF) models adopt this perspective, prescribing a dynamic rule with which the criterion for proceeding with or abandoning an investment is continuously reviewed in line with NPV calculation that reflects latest profitability prospects.

Graham and Harvey (2001) observed that the neoclassical approach to investment appraisal is powerful and useful but limited in two respects. First, it fails to offer much insight into how uncertainty could influence investment. Second, it cannot explain the role of sunk costs in investment decisions.

Harrigan (1981) agreed that sunk costs matter for capital adjustment. Firms could choose to remain in the industry because they have invested heavily in existing assets (physical or intangible) for which the expenditures cannot be fully recovered in the event of business closure.

In the context of agriculture, Johnson (1960) discussed how production responses are generally nonsymmetric—that is, supply elasticity tends to be smaller for an output price decrease than for an output price increase. He postulated that the requirement for lump-sum investment in land and labor leads to a delay in entry—even given a strong prospect of output price increases—and, correspondingly, a delay in exit except at very low output prices.

Real-world investment practices often provide little support to static, deterministic NPV analysis. Summers (1987) interviewed experienced investors about how they assessed prospective investments. Interview results revealed a typical behavior of investors applying hurdle rates three to four times higher than the cost of capital. Dixit and Pindyck (1995) examined evidence from corporate disinvestment decisions showing that many companies would stay in business while absorbing large operating losses for long periods. For these companies, output prices could fall appreciably below average variable costs without inducing business closure.

The advance of financial-options theory opens up a new perspective for understanding firm behavior in making investment decisions. Brennan and Schwartz (1985) and McDonald and Siegel (1985) , among many others, adapted the techniques developed for financial options to the modeling of physical asset investment. Dixit (1989, 1991) and Dixit and Pindyck (1994) formalized the application of real-options theory by considering irreversible investment under uncertainty. A key insight of the Dixit–Pindyck model is the derivation of investment trigger rates that take into account the economic value of an option to wait. Since their pioneering work, there have been growing uses of the real-options approach to analyze investment in a variety of industry settings.

Examples for agriculture abound. Using a real-options model, Luong and Tauer (2006) studied coffee growers' investment in Vietnam. Price and Wetzstein (1999) looked at investment in peach orchards in Georgia. Tauer (2006) investigated market conditions prompting investors to get in and out of the dairy sector in the United States. Schmit et al. (2009) analyzed ethanol plant investment in the United States. Seo et al. (2004) examined table grape production in California.

The real-options approach is suitable for this study because wine grape production is characterized by large sunk capital expenditures and uncertain revenues. Wine grape production requires upfront capital costs for planting grapevines and installing vineyard infrastructure, equipment, and machinery. Most of these inputs, once put in place, cannot be recovered, relocated, or used on-site for other purposes. Furthermore, perennial grapevines require careful nurturing and maintenance in the first few years after planting before they can grow to become a fruitful and revenue-generating asset. Even then, at a stage of maturity for harvest, revenue is highly uncertain due to many risk factors, such as commodity price fluctuation, demand shift, weather, and environmental influences on crop yield.

III. Model Formulation

In this study, the focus of analysis is on assessing the strategic value of waiting to exit or enter wine grape production. We did not consider a broader range of investment options, such as mothballing vineyard operations temporarily, leasing out land and water titles, and switching to growing a different variety of grapes.

Accordingly, the estimated value of waiting is inclusive of various strategic options that could be relevant to particular wine grape growers. For example, growers may choose to re-enter with a different variety or mix of varieties from those in existing operations.

We assumed that revenue uncertainty is the primary source of investment risk. Accordingly, capital expenditures and other production costs are relatively stable, predictable, and not contributing to uncertainty.

We specified revenue uncertainty in a similar way to the approach used by both Dixit and Pindyck (1994) and Price and Wetzstein (1999). Dixit and Pindyck (1994) assumed only price uncertainty. Drawing on the work by Hull (1997), Price and Wetzstein (1999) devised a real-options model with the dual source of price–yield uncertainty. In this context, revenue is the product of price and yield rate. Revenue uncertainty reflects not only the separate volatility in price and yield but also the correlation between them.

We assumed both price P and yield Q follow a geometric Brownian motion process:

$$dP = \mu_P P dt + \sigma_P P dz_P \tag{1}$$

$$dQ = \mu_Q Q dt + \sigma_Q Q dz_Q \tag{2}$$

where dP and dQ, respectively, represent the change in per-ton seasonal price and the change in per-hectare seasonal yield rate and, with subscripts P and Q denoting price and yield, μ is the drift rate, and σ the standard deviation of the stochastic process. Furthermore, dz denotes an increment of the Wiener process with $E(dz_P^2) = E(dz_Q^2) = dt$ and $E(dz_P, dz_Q) = \rho dt$, ρ being the correlation coefficient between P and Q.

Dixit and Pindyck (1994) assumed risk neutrality and maximization of expected NPV from investment. We adopted the same assumptions. A further assumption is the log-normal distribution of revenue, $R = PQ$, as the product of price and quantity. Accordingly, the mean and variance of seasonal revenue change are both independent of the revenue level (Hull 1997). The stochastic process of R is determined by the differential of the change in logarithm of R, $dr = d\ln(R)$. Hence, following Ito's lemma:

$$dr = \frac{\partial r}{\partial P} dP + \frac{\partial r}{\partial Q} dQ + \frac{1}{2}\frac{\partial^2 r}{\partial P \partial Q} dP dQ + \frac{1}{2}\frac{\partial^2 r}{\partial P^2} dP^2 + \frac{1}{2}\frac{\partial^2 r}{\partial Q^2} dQ. \tag{3}$$

Since

$$\frac{\partial r}{\partial P} = \frac{1}{P}, \quad \frac{\partial r}{\partial Q} = \frac{1}{Q}, \quad \frac{\partial^2 r}{\partial P^2} = -\frac{1}{P^2}, \quad \frac{\partial^2 r}{\partial Q^2} = -\frac{1}{Q^2}, \text{ and } \frac{\partial^2 r}{\partial P \partial Q} = 0,$$

equation (3) reduces to

$$dr = \frac{1}{P}dP + \frac{1}{Q}dQ - \frac{1}{2P^2}dP^2 - \frac{1}{2}\frac{1}{Q^2}dQ^2. \tag{4}$$

Equations (1) and (2) can be substituted for dP and dQ in equation (4). As $(dt)(dz)$ is of order $(dt)^{3/2}$, every term with dt raised to a power greater than 1 approaches 0 faster than dt does in the limit. This yields:

$$dr = \left(\mu_P + \mu_Q - \frac{1}{2}\sigma_P^2 - \frac{1}{2}\sigma_Q^2\right)dt + \sigma_P dz_P + \sigma_Q dz_Q. \tag{5}$$

Thus, $r = \ln(R)$ follows a Brownian motion process of the general form $dr = \mu_r\, dt + \sigma_r\, dz_r$ implying that dr over a time interval T is normally distributed with mean μ_r equal to:

$$\left(\mu_P + \mu_Q - \frac{1}{2}\sigma_P^2 - \frac{1}{2}\sigma_Q^2\right)T \tag{6}$$

and variance σ_r^2 equal to:

$$(\sigma_P^2 + \sigma_Q^2 + 2\rho\sigma_P\sigma_Q)T. \tag{7}$$

Applying Ito's lemma to $R = e^r$ yields the geometric Brownian motion process for revenue change:

$$dR = \mu_R R dt + \sigma_r R dz_R \tag{8}$$

where $\mu_R = \mu_r + \frac{1}{2}\sigma_r^2$.

Based on the stochastic process of revenue, the real-options model of investment is expressed as:

$$V_0(R) = BR^{\beta} \tag{9}$$

$$V_1(R) = R/\left(\delta - \mu_R\right) - C/\delta + AR^{-\alpha} \tag{10}$$

where $V_0(R)$ denotes the expected present value of entering into wine grape production (idle project) with R based on the stochastic process (8), and $V_1(R)$ denotes the expected present value of existing wine grape production (active project). Furthermore, parameters α and β denote the two roots of the quadratic equation (Dixit, 1991), δ the discount rate, μ_R the revenue drift rate, and C the total variable cost of production.

Dixit and Pindyck (1994) formulated the optimal strategies for entry and exit in terms of two threshold annual rates of revenue per hectare, R_H and R_L.

Accordingly, new investors enter into wine grape production as long as revenue rises above R_H, and growers currently in production continue producing until revenue falls below R_L. Between the entry and exit triggers is an indeterminate range for both entry and exit decisions—a zone of hysteresis or inactivity, where investment incentives are muted because it is costly to reverse economic actions and, as a result, inaction is an optimal response.

These revenue triggers can be derived based on the value-matching condition and the smooth-pasting condition. The value-matching condition stipulates that, at the entry trigger point R_H, the value of a new investment (i.e., the value of the option to invest) must be equal to the value of the existing investment minus the sunk cost K (Equation 11). At the exit trigger point R_L, the value of the option to abandon production is equal to the value of the existing investment minus the net cost of abandonment X (Equation 13; noting that X is negative when it represents a positive net salvage value, as in this study). These triggers define the critical levels of revenue at which the new and incumbent investors find it optimal, respectively, to enter (R_H) or to abandon (R_L). The smooth-pasting condition requires that the two investment value functions meet tangentially at those threshold revenue rates. These two equalities lead to a system of four equations:

$$R_H/(\delta-\mu_R)-C/\delta+AR_H^{-\alpha}-BR_H^{\beta}=K \tag{11}$$

$$1/(\delta-\mu_R)-\alpha AR_H^{-\alpha-1}-\beta BR_H^{\beta-1}=0 \tag{12}$$

$$R_L/(\delta-\mu_R)-C/\delta+AR_L^{-\alpha}-BR_L^{\beta}=-X \tag{13}$$

$$1/(\delta-\mu_R)-\alpha AR_L^{-\alpha-1}-\beta BR_L^{\beta-1}=0 \tag{14}$$

where A and B are coefficients to be determined along with R_H and R_L.

As these equations are nonlinear in the variables R_H and R_L, no closed-form analytical solution exists. The revenue trigger for entry (R_H) and that for exit (R_L) were obtained by solving Equations (11) to (14) simultaneously through an iterative solution procedure solved by MATLAB programming.

The conventional approach to investment decision can be considered a special case of the model in which uncertainty, hence strategic response, is ignored. We implemented this special case by setting a zero-revenue drift rate and equating the coefficients A and B to zero. Under this setting, the entry trigger is $C+\delta K$, and the exit trigger is $C-\delta X$. These simplified trigger variables are consistent with the static, deterministic NPV investment rule, providing a basis for comparing the impact of revenue uncertainty and sunk cost consideration on investment under the alternative stochastic setting.

IV. Data Sources and Limitations

Estimating the real-options model requires data on wine grape price, yield, planted area, discount rate, total establishment cost, and total variable cost. There are no time-series data available for directly measuring seasonal revenues of wine grape production in northwest Victoria. Separate price and yield series are available, but they cannot be multiplied together to derive a revenue series because of differences in data measurement and classification. Out of practical necessity, we algebraically established the stochastic property of revenue uncertainty using statistical analysis results obtained for the price and yield series.

Data availability dictated the selection of 2005–06 as the reference year for modeling. We obtained cost data from two studies: (i) the 2007 Australian Bureau of Agricultural and Resource Economics (ABARE) study of vineyard performance commissioned by the Mildura–Wentworth Horticultural Task Force (Mues and Rodriguez, 2007); and (ii) the 2007 study conducted by Scholefield Robinson Mildura on behalf of the Australian Dried Fruits Association (Swinburn and MacGregor, 2007).

To construct the price variable, we used the ABARE Australia-wide wine grape price series over the period 1991–92 to 2009–10 as a proxy for the annual average price of wine grape in northwest Victoria. An examination of shorter price series for individual grape varieties grown in the region confirmed a high correlation between the national and regional prices and, hence, the suitability of the ABARE series for the statistical analysis. Those regional varietal price data were available from the Murray Darling/Swan Hill Wine Grape Crush Survey conducted by the Victorian Department of Primary Industries. For the period 1999 to 2010, the regional average wine grape price series (weighted by varietal production) shows a statistical correlation of 0.8 with the ABARE series.

To construct the yield variable, we sourced wine grape yield rates from the Australian Bureau of Statistics (ABS) wine and grape industry survey. These data are specific to the wine grape-growing areas in northwest Victoria.

Several data limitations necessitate caution in interpreting the modeling results. First, the latest information on the costs of grape vineyards in northwest Victoria is available only up to 2006. Without access to more up-to-date data, we do not make claims to the absolute relevance of the study to current conditions.

Second, the data on operating costs represent a combination of wine grape, table grape, and dried vine fruit production. The data source (ABARE) provides no separation of cost data for these activities. Using the combined dataset to calibrate the model for wine grape production could lead to moderate overstatement of the costs.

Third, the data on vineyard establishment costs from the Scholefield Robinson Mildura report are pertinent to dried grape production. Using these data could lead

Table 1
Establishment Costs by Vineyard Size (A$/ha)

Item	*Small*	*Medium*	*Large*
Land and water	32,328	30,607	28,578
Irrigation infrastructure	6,860	6,860	6,860
Vine establishment	13,377	13,377	13,377
Contract operations	4,330	4,330	4,330
Machinery	16,325	12,057	7,510
Total	73,213	67,224	60,648

Source: Swinburn and MacGregor (2007).

to overstatement of vine planting costs and understatement of machinery costs, which offset each other to a degree. Costs differ between dried grape and wine grape production for two reasons. First, in the establishment period, dried grape vineyards require more labor input than do wine grape vineyards. Second, hand harvesting is required for dried grape production while harvesting of wine grapes is mostly done with machines.

We estimated the model separately for three vineyard sizes based on the survey stratification by ABARE. The first refers to a group of small vineyards, with a planted area of 6 hectares (ha) per vineyard on average. The second refers to a group of medium-size vineyards, with a planted area of 13 ha on average. The third comprises larger vineyards, with a planted area of 52 ha on average.

Estimates of various establishment costs are listed in Table 1 for each vineyard size. To establish a new vineyard, capital expenses are incurred for purchasing land and water titles, constructing irrigation systems, trellising, and acquiring machinery and equipment. These expenses spread over a period of around two to three years before a new vineyard can yield a commercial harvest.

Averaged estimates of variable costs by vineyard size are listed in Table 2. Labor (inclusive of hired and family labor) is a major part of the total variable cost. Grape production is labor intensive. Weeding, pruning, and harvesting are mostly done by manual labor, although larger-scale wine grape production tends to be mechanized.

Depreciation is another key component of the total variable cost. This cost was imputed for depreciable assets—including vines but exclusive of land and water titles. Maintenance investment in the form of partial replanting is necessary to prevent a decline in productive capacity for vineyard production. To smooth replanting expenses between years, it is common for a vineyard to have block areas planted with vines of different ages. This enables replanting to be carried out across the whole vineyard on a yearly rotational basis. For individual vineyards, replanting decisions would depend on the age of vines. In the present model, the depreciation cost for annual replanting was estimated to reflect an average profile of vine ages across the study region.

Table 2
Variable Costs by Vineyard Size (A$/ha)

Item	*Small*	*Medium*	*Large*
Hired labor	2,036	1,665	1,239
Family labor	5,362	3,308	906
Fertilizers	449	199	339
Chemicals	654	473	293
Fuel, oil, and grease	882	372	339
Repairs and maintenance	974	642	583
Contracts	1,325	1,023	990
Depreciation	1,461	1,075	471
Other costs	5,773	4,393	2,691
Total	18,915	13,150	7,849

Source: Mues and Rodriguez (2007).

Table 3
Salvage Asset Values by Vineyard Size (A$/ha)

Item	*Salvage Rate*	*Small*	*Medium*	*Large*
Land and water	100%	32,328	30,607	28,578
Irrigation infrastructure	10%	686	686	686
Vine establishment	10%	1,338	1,338	1,338
Contract operations	0%	0	0	0
Machinery	20%	3,265	2,411	1,502
Minus:				
3% commission on sales of land and water		970	918	857
Termination fees		4,734	4,734	4,734
Removal of planting and irrigation infrastructure		3,840	3,600	3,540
Net total		28,672	25,910	22,973

Source: Authors' estimation based on cost data as presented in Table 1 and expert advice on salvage rate.

As shown in Tables 1 and 2, wine grape production costs vary with vineyard size. The unit-cost savings for larger vineyards are attributable to economized use of labor and other key inputs such as fertilizers, chemicals, and fuels. Per-hectare land-cost estimates are also lower for larger vineyards, reflecting cost savings associated with higher planting ratios per whole-vineyard area and lower unit costs of land preparation work. However, crop yield rates show only modest variation across different vineyard sizes. Together, the unit cost of production and the yield rate suggest significant economies of scale in wine grape production.

Estimates of salvaged asset values are summarized in Table 3. We assumed that upon vineyard closure, 10 percent of the infrastructure and vine establishment costs and 20 percent of machinery costs can be recovered through the sale of such assets. Land and water titles can be sold at market prices. It is costly to remove the abandoned vines and irrigation infrastructure. Growers may also need to pay termination fees for transfer of water titles out of their irrigation district.

The premise underlying real-options analysis requires that the stochastic variables of price and yield each follow a random walk. We confirmed this through performing unit-root tests as follows.

Annual per-hectare yield rate Q and per-ton price P were both modeled in the form of:

$$D_{it} = \lambda D_{it-1} + u_{it} \tag{15}$$

where D_{it} alternately represents the price and quantity at time t, and u_{it} is an independent error variable with zero mean and constant variance σ_u^2. Subtracting D_{it} from both sides of equation (15) yields:

$$D_{it} - D_{it-1} = \lambda D_{it-1} - D_{it-1} + u_{it} \tag{16}$$

$$\Delta D_{it} = \gamma D_{it-1} + u_{it}, \tag{17}$$

where $\gamma = (\lambda - 1)$.

Under the null hypothesis that the coefficient $\gamma = 0$ (i.e., $\lambda = 1$), the formulation would be consistent with a random-walk model. We tested the hypothesis for three variants of the random-walk model: (i) no constant and no trend; (ii) with constant and no trend; and (iii) with constant and trend:

$$\Delta D_{it} = \gamma D_{it-1} + u_{it} \tag{i}$$

$$\Delta D_{it} = \alpha_{it} \ + \gamma D_{it-1} + u_{it} \tag{ii}$$

$$\Delta D_{it} = \alpha_{it} \ + \gamma D_{it-1} + \kappa t \ \ + u_{it}. \tag{iii}$$

Using annual price data from 1992 to 2008, the Dickey–Fuller unit-root test failed to reject at 5 percent of statistical significance the null hypothesis that the price series follows a random walk for all three variant models.

For the yield series, the null hypothesis was not rejected for the first two random-walk equations but was rejected for the third one. Given these unit-root test results, we concluded that both the price and the yield series follow a random walk.

The estimation of the drift and variance for the price and yield series was based on the method outlined by Hull (1997). Table 4 shows the baseline parameter values of the real-options model.

V. Baseline Results

Table 5 presents estimates of the revenue triggers for entry and exit under the conventional and real-options approaches. As a basis for comparison, the conventional triggers represent the entry and exit criteria based on a static,

Table 4

Baseline Model Parameters

Parameter	*Description*	*Estimate*
μ_P	Price drift rate	0.0417
σ_P^2	Price variance	0.0281
μ_Q	Yield drift rate	0.0161
σ_Q^2	Yield variance	0.0443
ρ_{PQ}	Price and yield correlation	–0.1983
$\sigma_r^2 = \sigma_Q^2 + \sigma_P^2 + 2\rho_{PQ}\sigma_Q\sigma_P$	Revenue variance	0.0584
$\mu_R = \mu_r + 1/2\sigma_r^2$	Revenue drift rate	0.0507
δ	Opportunity cost of capital	0.0800

Table 5

Estimates of Revenue Triggers for Entry and Exit by Vineyard Size

	Small	*Medium*	*Large*
Conventional approach			
Entry (A$/ha)	24,772	18,528	12,701
Exit (A$/ha)	21,209	15,223	9,687
Real-options approach			
Entry (A$/ha)	34,258	28,981	18,119
Exit (A$/ha)	13,042	8,985	5,377

deterministic assessment of investment value. Between the entry and exit triggers is an indeterminate revenue range where investment and disinvestment incentives are muted. For an operating business, this inactivity reflects the significance of sunk costs in discouraging exit from the investment that no longer has the prospect of yielding the required return on capital. For a new investor, revenue uncertainty can deter entry unless the current prospect of revenue streams points to a significant premium over the opportunity cost of capital.

By accounting for the effect of revenue risk in a real-options context, the modeling produced higher estimates of the entry trigger and lower estimates of the exit trigger than under the conventional approach. Price and yield uncertainties were modeled to widen the gap between these triggers, adding to the propensity for muted investment response. This widened tolerance range for inactivity reflects investment hysteresis resulting from the interaction between sunk cost and uncertainty. If there were no sunk costs, there would be no hysteresis; with sunk costs, uncertainty becomes an important factor in the decision to invest or disinvest.

The real-options approach rectified the omission of strategic investment value in the conventional calculation, yielding a more rigorous estimate of the exit trigger at $13,042 for small vineyards. This represents a 39 percent downward adjustment from the conventional breakeven point, reflecting the real-options value in waiting to exit later. The vineyards may operate at a loss and yet stay in business with the expectation that the future will be better. However, exit will be rational if their revenue falls below the critical level where the loss is too great to offset the value of waiting.

Likewise for medium-size vineyards, the estimated exit trigger at $8,985 (compared with the conventional breakeven point at $15,223) highlights the economic rationale for enduring operating losses. Large vineyards would also have a lower propensity for disinvestment when the real-options value of waiting is taken into account.

Across all vineyard-size groups, the strategic entry trigger point was estimated to be much higher than the conventional trigger for new investment. For example for small vineyards, the required return on capital increased from an assumed rate of 8 percent to roughly 21 per cent. In other words, the conventional approach understates the financial hurdle for attracting new investment to wine grape.

VI. Sensitivity Analysis

We analyzed the sensitivity of investment thresholds to revenue variability, total variable cost, and liquidation value in order to understand how these vineyard characteristics could affect exit and entry decisions. The analysis was conducted primarily for small vineyards because they dominate the regional sector and are considered most vulnerable to exit pressures (as confirmed by the baseline results).

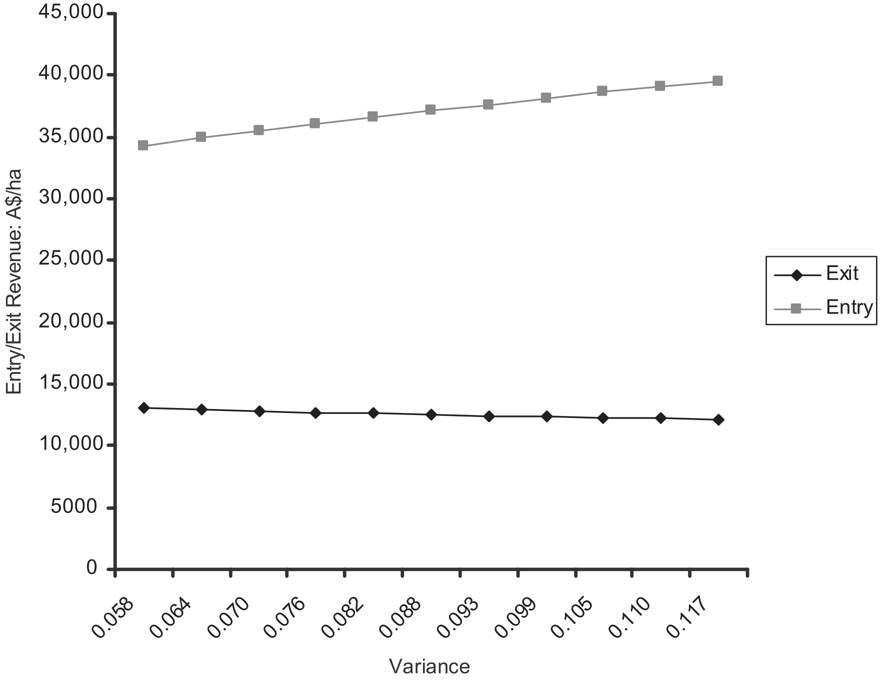
A. *Change in Volatility of Revenue*

To examine how the variance of revenue change could affect exit and entry decisions, we looked at a number of step changes in revenue variance. For a 10 percent increase in revenue variance from the baseline level (i.e., from 0.058 to 0.064), the exit trigger was estimated to fall from $13,042 to $12,901, and the entry trigger to rise from $34,258 to $34,891. If the variance were to double from the baseline (i.e., reaching 0.117), the entry trigger would be adjusted upward to $39,537 and the exit trigger would be adjusted downward to $12,110. The sensitivity test results for a broader range of variance changes are plotted in Figure 1, confirming the widening of the inactivity gap with increased revenue variance.

Increased revenue variance means greater potential for revenue increases in the future and implies a greater incentive for potential investors to delay entry into the sector upon confirmation of more favorable revenue prospects. By the same token, existing vineyards would be more strongly incentivized to stay in operation by a greater possibility of revenue improvement. This explains the inertia of many vineyards to stay in business despite sustained profit pressures amid increased revenue uncertainty.

Figure 1

Widening of Inactivity Gap with Increased Revenue Variance for Small Vineyards



B. *Change in Variable Cost*

Ryan (2007) discussed business strategies involving collaboration and cooperation for horticultural properties to achieve economies of scale. Collaboration could be as simple as two nearby vineyards combining growing areas or sharing machinery, labor, and irrigation equipment. Alternatively, groups of growers could form alliances to share access to technology and market information. Positive outcomes from these and other strategies in achieving a lower unit-cost of production could help growers endure cyclical economic downturns.

A distinctive advantage of collaboration and cooperation as a way to attain economies of scale is that these strategies do not require existing producers to disinvest and liquidate their vineyards. By contrast, sectoral consolidation that involves some vineyards or new investors acquiring other existing vineyards would incur considerable transaction costs. Such a costly consolidation process is also likely to face the hurdle relating to investment indeterminacy—that is, the difficulty in getting the incumbent and new investors to have compatible revenue expectations in order to justify, respectively, exit and entry as necessary for deal-making success. Notwithstanding the potential for improving business viability and endurance, critical factors necessary to yield successful outcomes from producing on a larger scale should not be overlooked.

According to the cost estimates shown in Tables 1 and 2, with two small wine grape vineyards combining to operate on a medium scale, per-hectare total establishment cost could decline by 8 percent while the resulting reduction in total operating cost could be even greater, at 30 percent. Similarly, medium-size vineyards that are able to catch up with large vineyards in efficiency terms would see their operating costs reduced by 40 percent. However, it would require merging up to four vineyards that are medium in size to achieve a cost reduction of this magnitude.

The dependence of investment incentives on scale economies was tested by modeling reductions in total variable cost while holding constant the levels of revenue, total establishment cost, and salvage value. With this method, the first type of sensitivity test on scale economies simulated small vineyards merging to operate in a medium scale and medium-size vineyards merging to operate in a large-vineyard scale. In these calculations, both the entry and exit triggers would fall with the assumed expansion in vineyard scale.

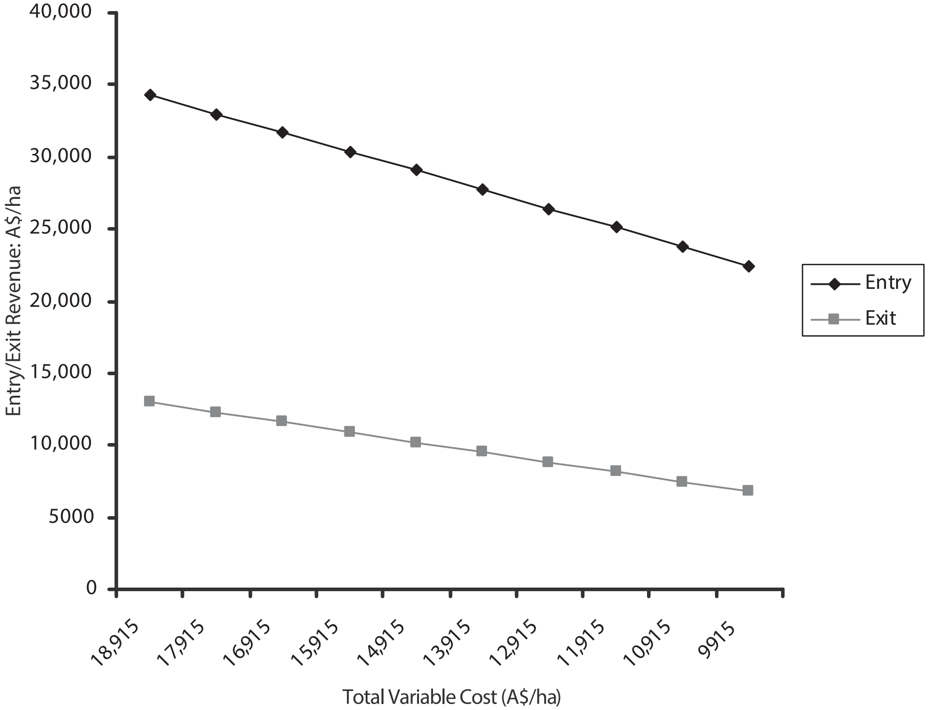
Improved cost efficiency does not necessarily have to come from merging activities; it could also result from incremental productivity gains. To simulate this, we conducted sensitivity analysis of incremental cost reductions for small vineyards. A reduction in total variable cost of $1,000 from the baseline, for instance, would lower the exit trigger by 6 percent. If total variable cost falls by $3,000, not surprisingly, the exit trigger would fall by even more, at 17 percent compared to baseline. The estimated relationships between the revenue triggers for entry and exit and total variable cost are displayed in Figure 2.

C. *Liquidation Value*

We conducted sensitivity analysis on salvageable infrastructure, which, upon exit, might be resold or used for some other purpose. The implications for investment incentives were analyzed by adjusting upward the salvage rate of irrigation infrastructure assets from 10 percent to 50 percent. This could represent an outcome of research and development in portable irrigation systems aimed at increasing salvage or liquidation value. The use of mobile infrastructure would have an effect of increasing the exit trigger by 4 percent for small vineyards, and 2 percent for medium-size vineyards. Consequently, infrastructure portability is a weak driver of exit decisions as this infrastructure cost is small relative to total establishment cost.

Figure 2

Narrowing of Inactivity Gap with Reduced Total Variable Cost for Small Vineyards



VII. Conclusion

This study set out to investigate the sluggish adjustment of the wine grape sector in northwest Victoria, Australia, in response to persistent profit pressures in recent years. Through the lens of real-options valuation, the study analyzed the investment incentives behind growers' decision to exit or stay in business under revenue uncertainty.

Significant sunk costs and volatile seasonal revenues for wine grape production were found to have underpinned a significant economic value in waiting to exit and enter. The modeling identified wide tolerance for low revenues where existing growers could find it worthwhile to stay in business despite not earning an attractive rate of return on their capital investment or even not earning enough to cover operating costs. The real-options value of waiting provides an economic rationale for enduring operating losses over an extended period. Sunk costs give growers an incumbency advantage in hanging on. Volatile revenues give them hope for a better future. For new investors, initial capital requirements represent a high price for entering the sector to start production. Revenue volatility adds to the rationality of entering at a later time, when the revenue outlook becomes sufficiently attractive.

It should be noted that these findings might not precisely fit with the experiences and circumstances of particular growers. This is because the model was based on averaged price and yield behavior as well as averaged cost structures of wine grape production in the study region. Moreover, the model was not designed to capture a broader range of personal influences on investment, such as the age of the vineyard owner (which may affect risk preferences and management capabilities), off-farm employment opportunities, amenity values of on-farm living, and capital market constraints.

It would certainly be useful and, in particular for policy development, necessary to consider all relevant socioeconomic factors and their interaction effects for a comprehensive understanding of the barriers to sectoral adjustment. A major contribution of the present model—despite its somewhat narrow focus on economic rationality—is the identification of the strong influence of incentive constraints on investment as a plausible explanation for the slow pace of sectoral adjustment. The underlying emphasis on the economic value of waiting is arguably most pertinent to vineyard production being undertaken as a "pure" investment. Yet for a broader analytical perspective, it appears that the model is expandable to accommodate a range of relevant socioeconomic factors. A suggestive approach would be to explicitly link these factors to key model components, such as salvage value, options range, and risk specification. This and other approaches are worth exploring within the real-options framework in further research.

In relation to the economics of vineyard investment, both the real-options and conventional approaches identify a range of revenue levels compatible with indeterminate entry or exit decisions. The conventional approach is, however, deficient in capturing the strategic value of waiting and, as a result, fails to robustly explain the prevalence of hysteresis or inactivity as a rational response to uncertainty when making decision on irreversible investment. Real-options analysis rectifies this deficiency by highlighting a much wider revenue range for investment indeterminacy to reflect a "wait-it-out" strategy.

Investment indeterminacy has significant implications for industry policy aimed at facilitating sectoral restructuring and transformation. This phenomenon signifies the inertia in capital adjustment that is manifested in the inability of market mechanisms to align investment incentives and overcome investment hysteresis in times of adverse market conditions. Specifically, an existing vineyard business holds the valuable option of waiting despite minimal or even negative profitability. With this option in place, prospective buyers of the vineyard business or its key assets such as the land would have to pay for all or part of the owner's option in order to induce a sale—even if the option carries little value for them. Consequently, what appears economically rational for growers and investors does not lead to an economically efficient market outcome.

Where market mechanisms are frustrated by noncompatible investment incentives, there can be a legitimate role for government intervention to ease the adjustment process in order to expedite the realization of efficiency gains from industry restructuring. A fundamental policy objective is to reduce investment indeterminacy in vineyard asset markets, thereby improving the responsiveness and effectiveness of market mechanisms in bringing about necessary sectoral adjustments to ensure efficient investment and production.

In this connection, the study looked at the outcome of promoting larger-scale production to reduce the revenue range that is susceptible to muted investment response. The existence of economies of scale was shown to have the effect of reducing the relative significance of sunk costs in total costs and, hence, the scope for creating the strategic value (i.e., opportunity cost) in waiting to exit and enter for vineyards of a larger size.

Despite the obvious merit of scale-efficient production, there are practical hurdles to reaping efficiency gains through vineyard consolidation. The core one is the decentralization of decision making by individual growers. While facing market pressures, they could make different responses, depending on their previous financial decisions (including timing and business strategy), life-cycle stage, participation in off-farm employment, and confidence in the future.

The impact of fragmented decision making could be exacerbated by inconsistent policy initiatives. For example, growers in northwest Victoria often faced the choice between accepting government assistance for deepening on-farm investment and accepting an exit grant for abandoning the business. In such circumstances, their choice was virtually irreversible and could have externalities on others—by accepting the exit grant, the grower would have to cease irrigation for five years and decommission all on-farm irrigation infrastructure, increasing the burden of maintenance on other users of the regional irrigation system. The growers' different responses had led to a map of vineyard properties scattered with dried land blocks. This dispersion of properties vividly demonstrates the difficulty of amalgamating contiguous plots of land.

The small-block problem underlies the case for corrective intervention to address pre-existing policy-induced market distortions. To a large extent, small-block farming in northwest Victoria was a legacy of soldier settlement after World War I. Because advances in farm mechanization created a new scope for scale economies in the modern era, the policy legacy—by sustaining a farming structure that is profoundly uneconomical from today's perspective—has become a persistent impediment to market adjustment and sectoral transformation. Farm programs that provide exit assistance to growers leaving the sector could help strengthen growers' propensity to exit due to loss-making production.

The study also identified a direct relationship between increased revenue variance and increased investment hysteresis. Accordingly, a reduction in policy uncertainty that contributes to the perception of revenue volatility could help elicit responsive vineyard adjustments by strengthening the profit incentives for investment and disinvestment. Contradictory incentives are created between government programs aimed at providing financial relief in times of a business downturn or natural adversity (e.g., drought and flooding assistance schemes) and those aimed at aiding business relocation or restructuring (e.g., exit and grubbing-up plans). Improving sectoral adjustment responsiveness through a reduction of the option value of waiting would call for consistency in vineyard policies between the objectives of facilitating exit and sustaining continuous production.

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