Savvy Investments: Vineyard Development in New Zealand's Premier Wine Producing Region

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Abstract

This paper uses the real options valuation technique to analyse Marlborough vineyard investment decisions. In particular, it develops a model that can be used to determine optimal investment and disinvestment points for potential vineyard investors. The study extends the traditional real options framework to accommodate for the investor to be potentially the owner of an existing sheep and beef farm. A numerical example is provided, calibrated to Marlborough data. The research studies the effect that vineyard location can have in determining the optimal behaviour of the investor.

1 Introduction

Since 1973, Marlborough has witnessed unprecedented change to the composition of its landscape. Diverging from predominately sheep and beef farming, Marlborough has quickly developed into New Zealand's premier wine producing region, currently accounting for 80% of the country's total wine production. Fuelling this expansion is the continued demand worldwide for the unique flavours Marlborough wine grapes consistently produce. However, the hasty expansion has created a severe oversupply issue within the region, putting pressure on the local industry. Since 2009, local vineyard owners have struggled with eroded grape prices, leading to a narrowing of vineyard profit margins. As a result, Marlborough's wine industry is increasingly more consolidated as large wineries continue to acquire many of the region's less established vineyards at distressed prices.

Given the importance of the Marlborough wine industry, both locally and nationally, the intension of this study is to provide insight into the effect that changing economic conditions have on Marlborough vineyard investment decisions. Using an extension of the real options pricing framework, this study will empirically calibrate a model that allows investment and disinvestment trigger points simulating optimal behaviour for Marlborough vineyard owners. The model will provide a better understanding of actual investor behaviour and determine whether their investment decisions were optimal.

McDonald and Siegel (1985), McDonald and Siegel (1986), Brennan and Schwartz (1985), and Majd and Pindyck (1987) adopt the valuation techniques developed for financial options to model physical asset investment and disinvestment decisions. A valuation technique coined real options analysis. Dixit (1989), Dixit (1992), and Dixit and Pindyck (1994) apply the real options framework to industrial entry and exit by examining irreversible investment under uncertainty. Real options valuation recognises that certain business initiatives, such as investment and disinvestment, that require extensive financial commitment and have uncertain future returns, can be characterised as financial options. The investment decision can be modeled as a call option, the disinvestment decision, a put.

Titman (1985) adopts the real options pricing framework to real estate where he estimates the value of undeveloped land. Undeveloped land, that can potentially be developed into buildings, represents the value of a call option with the strike price equal to the costs of construction. Future building prices are assumed uncertain. Childs, Riddiough, and Triantis (1996) also apply the real options method to real estate in order to analyse how different potential uses and redevelopment opportunities impact property values. Geltner, Riddiough, and Stojanovic (1994) who also look at the effect of land use. These early applications of the real options framework are directly relevant to this study as the research is analysing the development of land.

Agricultural applications of the real options framework include Tauer (2006) who determines optimal entry and exit strategies for diary farmers in the U.S., Price and Wetzstein (1999) who look at investment and disinvestment decisions for peach orchard owners in Georgia, and Luong and Tauer (2006) who analyse Vietnamese coffee growers' investment decisions. Vineyard specific applications include Seo, Smith, Mitchell, and Leatham (2004) who apply a real options analysis to table grape farming in California, Seyoum-Tegegn and Chan (2013) who provide optimal entry and exit in northwest Victoria, and Cyr, Hanagriff, and Kwong (2010) who perform the same for Texas. Richards and Green (2003) apply real options to grape varietal investment decisions. However, the previous applications have been generally limited to looking at a single stochastic component, often commodity price or revenue. In some cases it becomes necessary to realise a second stochastic component in order to find true optimal entry and exit triggers. Assuming only price or revenue to be stochastic appears naïve as costs and various other investment decision determinants potentially evolve according to a stochastic process.

This study addresses the shortfall in the literature by analysing a more realistic case where we assume that the investor is alternatively the owner of an operating sheep and beef farm whose profits follow a stochastic process. Schmit, Luo, and Conrad (2011) extend the traditional real options model so that it can accommodate for two stochastic variables for which they provide a quasi-analytical solution. However, this study takes a different perspective as the assumptions in order to provide quasi-analytical solutions seem unreasonable. This study assumes that the difference between vineyard profits and sheep and beef farm profits follows a stochastic process that can turn arbitrarily negative in the future. The Crank-Nicolson finite difference scheme is employed in order to provide a numerical solution.

Using a Marlborough specific dataset, this study determines per hectare values of vineyard land for various subregions in Marlborough. Local knowledge suggests that a portion of land within the Wairau Valley subregion is superior in terms of grape growing relative to the rest of the region. The study empirically calibrates the model to this section of the Wairau Valley subregion, known locally as "the Golden Triangle". A term coined by Pickford (2013). This allows the study to determine whether owners of land inside the Golden Triangle have different optimal behaviour from those with land elsewhere. However, the research does not find sufficient evidence supporting this hypothesis. Suggesting that the seemingly high status of the Golden Triangle is a mere misconception.

The remainder of this paper proceeds as follows: section 2 introduces the real options framework and outlines the development our model. Section 3 discusses the available data and its limitations. Empirical parameter estimates, critical investment and disinvestment points are then presented in section 4. Lastly, section 5 concludes.

2 Methodology

Wine grape production and sheep and beef farming are both characterised by the relatively broad upfront costs associated with establishment and uncertain future returns. These characteristics reasonably satisfy the requirements when following Dixit (1989), Dixit (1992), and Dixit and Pindyck (1994). Wine grape is a perennial crop and vineyard owners regularly replace grape vines when they lose their ability to produce high yield crop. Therefore, the vineyard investment decision is assumed infinitely lived as there are both ongoing revenues and expenses relating to wine grape production. Sheep and beef farming is also assumed infinitely lived as land has an infinite life and sheep and beef stock are replaced regularly. Real options recognises that these characteristics may cause the investor to defer investment or disinvestment due to the extensive establishment costs and the stochastic nature of profits for the two farm types.

The following models rely on the preceding underlying basic concepts. The potential investment decision to convert an exiting sheep and beef farm into an operational vineyard represents the value of a call option with an exercise price equal to the fixed costs associated with establishment, k. A vineyard in operation receives profit over what could be earned by a sheep and beef farm, $\psi = y - x$, where y is the profit per hectare of a vineyard and x is the profit per hectare of a sheep and beef farm. Along with excess profits, the value of an active vineyard implicitly includes the value of a put option to disinvest with exercise price equal to the costs associated with converting a vineyard back into an operational sheep and beef farm, l.

We assume vineyard profit per hectare and sheep and beef farm profit per hectare to be stochastic and evolve according to a geometric Brownian motion

$$dy = \mu_y y dy + \sigma_y y dZ_y \tag{1}$$

$$dx = \mu_x x dx + \sigma_x x dZ_x. \tag{2}$$

$f(x)$ denotes the value of a sheep and beef farm, where

$$f(x) = \frac{x}{\delta - \mu_x}. \tag{3}$$

Therefore the value of a non-active vineyard and the value of the active vineyard, in excess of a perpetual farm are denoted by $f(x) + V_0(x, y)$ and $f(x) + V_1(x, y)$ respectively. The discount rate, δ, is the fair expected return for the risk associated with vineyard/farm profits.

For this study ψ_H and ψ_L respectively represent the locus of points where conversion from a sheep and beef farm to a vineyard, and from a vineyard to a sheep and beef farm become optimal, where $\psi = x - y$ is modeled as stochastic. μ_ψ and σ_ψ respectively represent the drift rate and standard deviation for ψ. Lastly, Z is a Wiener process drawn from the normal distribution, $N(0, 1)$, with expectation $E[Z] = 0$.

Diverging from previous literature and the traditional real options framework, this study models the difference between vineyard profits and sheep and beef farm profits, $\psi = y - x$, as the stochastic component. This study, as shown above, assumes that the individual profits of the two farm types evolve according to a geometric Brownian motions. We therefore model the difference in the two profits as an arithmetic Brownian motion

$$d\psi = \mu_\psi dt + \sigma_\psi dZ_\psi. \tag{4}$$

This stochastic process allows x to exceed y by arbitrary amounts in the future rather than being fixed and included as an opportunity cost that could be use in the traditional application. In order to generate the partial differential equations we employ

Itō's lemma to yield the total differential of $V_i = V_i(x, y) = V_i(\psi)$

$$dV_i = \left(\frac{\partial V_i}{\partial \psi} \mu_\psi + \frac{1}{2} \frac{\partial^2 V_i}{\partial \psi^2} \sigma_\psi^2 \right) dt + \frac{\partial V_i}{\partial \psi} \sigma_\psi y dZ_\psi, \tag{5}$$

where $i = 0, 1$. Note the time derivative, $\partial V_i / \partial t$ has been deleted as this is an infinite horizon problem. Taking the expected value of both sides of equation (5) yields

$$E[dV_i] = \left(\frac{\partial V_i}{\partial \psi} \mu_\psi + \frac{1}{2} \frac{\partial^2 V_i}{\partial \psi^2} \sigma_\psi^2 \right) dt, \tag{6}$$

as the expected value of a standard normal deviate is zero. In equilibrium, the expected capital gain on the farm, $V_0(\psi)$, must be equal to the fair return on the value of the farm over the time increment, dt. The same is true for the expected capital gain on the active vineyard, $V_1(\psi)$, except the expected return on the active vineyard over dt will include the excess profits earned over dt. These are expressed as

$$E[dV_0] = \delta V_0 dt \tag{7}$$

$$E[dV_1] + (y - x)dt = \delta V_1 dt. \tag{8}$$

Equating equations (6) and (7), and (6) and (8), and dividing through by dt gives the partial differential equation expressions for the investments in equilibrium

$$\frac{\partial V_0}{\partial \psi} \mu_\psi + \frac{1}{2} \frac{\partial^2 V_0}{\partial \psi^2} \sigma_\psi^2 - \delta V_0 = 0 \tag{9}$$

$$\frac{\partial V_1}{\partial \psi} \mu_\psi + \frac{1}{2} \frac{\partial^2 V_1}{\partial \psi^2} \sigma_\psi^2 - \delta V_1 = x - y. \tag{10}$$

2.1 Solution - Numerical

In order to numerically solve the partial differential equations given in (6) and (7) we employ the Crank-Nicolson finite difference scheme. For this we add back the time differentials to the partial differential expressions. The partial differentials can now be expressed as

$$\frac{\partial V_0}{\partial \tau} = \frac{\partial V_0}{\partial \psi}\mu_\psi + \frac{1}{2}\frac{\partial^2 V_0}{\partial \psi^2}\sigma_\psi^2 - \delta V_0 \tag{11}$$

$$\frac{\partial V_1}{\partial \tau} = \frac{\partial V_1}{\partial \psi}\mu_\psi + \frac{1}{2}\frac{\partial^2 V_1}{\partial \psi^2}\sigma_\psi^2 - \delta V_1 + y - x, \tag{12}$$

where $\tau = T - t \to \partial V_i/\partial \tau = -\partial V_i/\partial t$. We restrict attention to a grid defined in the two dimensions ψ and t, where

$$\psi_j = \psi_0 + j\Delta\psi \qquad\qquad j = 1, ..., J$$

$$t_n = n\Delta t \qquad\qquad n = 1, ..., N.$$

$$V_{i,j}^n = V_i(\psi_j, t_n) \tag{13}$$

We let $V_{i,j}^n = V_i(\psi_j, t_n)$ equal the value of V_i when $\psi = \psi_j$ and $t = t_n$ with $V_{i,j}^n$ denoting the vector $[V_{i,1}^n, ..., V_{i,J}^n]'$. We approximate the ψ_j derivatives of V_i using

$$\frac{\partial V_i}{\partial \psi}(\psi_j, t_n) \approx \frac{V_{i,j+1}^n - V_{i,j-1}^n}{2\Delta\psi} \tag{14}$$

$$\frac{\partial^2 V_i}{\partial \psi^2}(\psi_j, t_n) \approx \frac{V_{i,j+1}^n - 2V_{i,j}^n + V_{i,j-1}^n}{(\Delta\psi)^2}. \tag{15}$$

The τ derivative is approximated by

$$\frac{\partial V_i}{\partial \tau}(\psi_j, \tau_n) \approx \frac{V_{i,j}^{n+1} - V_{i,j}^n}{(\Delta\tau)}. \tag{16}$$

At the boundary we angle the ψ_j derivatives of V_i in using

$$\frac{\partial V_i}{\partial \psi}(\psi_0, t_n) \approx \frac{-3V_{i,0}^n + 4V_{i,0+1}^n - V_{i,0+2}^n}{2\Delta\psi} \tag{17}$$

$$\frac{\partial^2 V_i}{\partial \psi^2}(\psi_1, t_n) \approx \frac{-V^n_{i,1+1} + 2V^n_{i,1} - V^n_{i,1-1}}{\Delta\psi^2}, \tag{18}$$

and

$$\frac{\partial V_i}{\partial \psi}(\psi_J, t_n) \approx \frac{3V^n_{i,J} - 4V^n_{i,J-1} + V^n_{i,J+2}}{2\Delta\psi} \tag{19}$$

$$\frac{\partial^2 V_i}{\partial \psi^2}(\psi_J, t_n) \approx \frac{V^n_{i,J+1} - 2V^n_{i,J} + V^n_{i,J-1}}{\Delta\psi^2}. \tag{20}$$

We now define a matrix, A, as the discretisation of the spatial terms in the partial differential equation in order to simplify the Crank-Nicolson approximation

$$A = \begin{bmatrix} a_0 & b_0 & c_0 & 0 & 0 & \dots & \dots & 0 \\ a_1 & b_1 & c_1 & 0 & 0 & \dots & \dots & 0 \\ 0 & a_2 & b_2 & c_2 & 0 & \dots & \dots & 0 \\ \vdots & & \ddots & \ddots & \ddots & & & \vdots \\ 0 & \dots & \dots & 0 & a_{J-2} & b_{J-2} & c_{J-2} & 0 \\ 0 & \dots & \dots & 0 & 0 & a_{J-1} & b_{J-1} & c_{J-1} \\ 0 & \dots & \dots & 0 & 0 & a_J & b_J & c_J \end{bmatrix},$$

where

$$a_0 = \frac{-3\mu_\psi}{2\Delta\psi} + \frac{\sigma_\psi^2}{2(\Delta\psi)^2} - \delta \qquad a_J = \frac{-\mu_\psi}{2\Delta\psi} + \frac{\sigma_\psi^2}{2(\Delta\psi)^2}$$

$$b_0 = \frac{2\mu_\psi}{\Delta\psi} - \frac{\sigma_\psi^2}{(\Delta\psi)^2} \qquad b_J = \frac{-2\mu_\psi}{\Delta\psi} - \frac{\sigma_\psi^2}{(\Delta\psi)^2}$$

$$c_0 = \frac{-\mu_\psi}{2\Delta\psi} + \frac{\sigma_\psi^2}{2(\Delta\psi)^2} \qquad c_J = \frac{3\mu_\psi}{2\Delta\psi} + \frac{\sigma_\psi^2}{2(\Delta\psi)^2} - \delta$$

and

$$a_j = \frac{-\mu_\psi}{2\Delta\psi} + \frac{\sigma_\psi^2}{2(\Delta\psi)^2} \qquad j = 2, ..., J-1$$

$$b_j = \frac{-\sigma_\psi^2}{(\Delta\psi)^2} - \delta \qquad j = 2, ..., J-1$$

$$c_j = \frac{\mu_\psi}{2\Delta\psi} + \frac{\sigma_\psi^2}{2(\Delta\psi)^2} \qquad j = 2, ..., J-1.$$

The Crank-Nicolson approximation becomes

$$\frac{V_i^{n+1} - V_i^n}{(\Delta\tau)} = \frac{1}{2}[AV_i^n + AV_i^{n+1}] + \frac{1}{2}(d_i^n + d_i^{n+1}), \tag{21}$$

where d_i equals 0 if $i = 0$ and $\psi_1, ..., \psi_J$ if $i = 1$. Rearranging yields

$$\left(\frac{1}{\Delta\tau} - \frac{1}{2}A\right)V_i^{n+1} - \frac{1}{2}d_i^{n+1} = \left(\frac{1}{\Delta\tau} + \frac{1}{2}A\right)V_i^n + \frac{1}{2}d_i^n, \tag{22}$$

which is a system of equations the research solves to find V_i^{n+1} given V_i^n. To solve, the study iterates backwards from the condition

$$V_i^0 = \frac{\psi}{\delta} + \frac{\mu_\psi}{\delta^2},$$

until $|V_i^n - V_i^{n+1}| > \epsilon$, where ϵ is a specified accuracy condition.

3 Data

To provide the necessary estimates of the establishment and disestablishment costs, k and l, and the stochastic process parameters, μ_ψ, μ_x, σ_ψ, δ, and GT, the research makes use of two types of data. Establishment and abandonment costs respectively depend on the various costs associated with vineyard establishment and disestablishment in Marlborough. The stochastic parameters are empirically calibrated using a combination of time series vineyard and sheep and beef farm profit data, and a vineyard transactions data set unique to Marlborough. The study also uses the vineyard transactions dataset in order to provide an estimate for the relative effectiveness of the Golden Triangle, GT.

3.1 Vineyard profit per ha (y)

Yearly vintage data was collected from various Horticulture Monitoring reports published by the Ministry for Primary Industries. Key financial results were gathered from the reports that provided estimates of the average operating costs and revenues of typical Marlborough vineyards for the period 2004-2012.

The Ministry uses a Marlborough vineyard model that reflects operational revenues and expenses sustained by a typical Marlborough grape grower. The model is determined using data from 18 local vineyards situated mostly in the Wairau Valley subregion. The model does include vineyards situated in other subregions such as the Awatere Valley and the Southern Valleys. However, they are not as pronounced in the Ministry's model. The model reflects an accurate representation of Marlborough's vineyards, as the Wairau Valley is the most densely populated with vineyards. The model assumes a producing area of 30 hectares and a varietal mix reflecting Marlborough's composition well with 75 percent of the vineyard planted as Sauvignon Blanc and the remaining area comprising of Pinot Noir, Chardonnay, Riesling and Pinot Gris.

A weighted average of grape prices per tonne is determined and then used to calculate revenue by multiplying the grape price by total production. Expenditure including labour expenses, weed and pest control, maintenance, harvesting and other overhead expenses are then deducted to give a cash operating surplus figure. Depreciation, interest, rent and/or leases are also deducted to yield a total vineyard profit before tax figure. This total is then divided by the effective producing area to give the profit before tax per hectare. Table 1 provides the time series summary of the Marlborough vineyard model's profit per hectare.

Profit before tax collapsed from $629,420 in 2008 to $108,070 in 2009. The significant decline in profits is directly linked to the over supply issue that confronted the industry in the 2009 vintage. Vineyard owners are traditionally price takers as wineries typically have leverage over how many grapes they buy and at what price they buy them. This custom was exacerbated with the oversupply as winery production was struggling to keep up with the supply. From Table 1 we can see that vineyard profits have continued to be depressed relative to vineyard profits pre-oversupply. This potentially is a sign that oversupply is still a significant issue within the industry. Further, we see that the producing area of the average Marlborough vineyard has increased over time, especially around the 2008 to 2010 period. This provides supportive evidence to the hypothesis that wineries purchased and amalgamated distressed vineyards around the time of the oversupply event.

Several limitations imply caution when interpreting the data. First, the short amount of data available makes it difficult to capture the full development of the Marlborough wine industry. Presumably, profits in earlier years were just as high, if not higher, than the recorded pre-oversupply profits. Further, the Ministry made a change to the sample of vineyards they surveyed in the year 2010. This study spliced the preceding years data in order to make them comparable with the 2010 to 2012 data.

3.2 Sheep and beef farm profit per ha (x)

Ministry for Primary Industries Farm Monitoring reports offer a similar model structure to that constructed for the Horticulture report. The Canterbury/Marlborough breeding and finishing sheep and beef report is used as it gives the most accurate representation of the farm type that was present before the region became vineyard oriented. The model is a representation of 1555 Canterbury and Marlborough breeding and finishing sheep and beef farms. The farms engage in a range of sheep and beef farming operations including sheep and cattle sales, wool and grazing. The models effective farming area is roughly 478 hectares for the year ended 2012. Farm profit is calculated in a similar way to that used for the Marlborough vineyard model, which we use to infer profit per hectare by dividing through by the effective farming area. Table 2 provides the time series summary profit per hectare for the Canterbury/Marlborough breeding and finishing sheep and beef farm model.

Comparing Table 1 and Table 2 we first notice that Marlborough vineyard profits substantially outperform sheep and beef farm profits on a per hectare basis. Not only do they outperform on a per hectare basis, but also the average sized vineyard of roughly 30 hectares has higher profits than an entire 460 hectare farm in some years. However, this is not hugely surprising given grape farming is a reasonably compact operation in terms of output per hectare compared to sheep and beef farming. The fact that the vineyards outperform sheep and beef farms on a regular basis is a preliminary insight into why so many sheep and beef farm owners converted portions of, or entire, sheep and beef operations into vineyards.

The short amount of data is again a limitation. A longer time series would provide a better analysis of the development of sheep and beef farm profits for earlier years.

Again, the Ministry altered the sample of farms in the year 2010. In order to make the preceding years comparable, the study splices the data. The Ministry's model does include the Canterbury sheep and beef farm data which arguably introduces some heterogeneity in the study. However, the heterogeneity in sheep and beef farming is assumed to be relatively small across the two regions as sheep and beef farming is seen as relatively homogenous compared to grape farming. An abundance of literature including Murray and Overton (2011), Overton (2010), and Jouanneau, Weaver, Nicolau, Herbst-Johnstone, Benkwitz, and Kilmartin (2012) have documented how large of an effect vineyard location has on production, marketing, and consumption of wines. This makes vineyard production particularly heterogenous compared to sheep and beef farming. In other words, it may not matter if beef or lamb originates from Canterbury or Marlborough, but there is a significant difference in grapes that come from different subregions in Marlborough.

The Ministry for Primary Industries also produces a hill country sheep and beef farm model. However, this is less relevant as one cannot convert an entire hill country sheep and beef farm into a vineyard due to complexities in topography. Although some have converted portions of their hill country sheep and beef farms into vineyards, the portions of land are better represented by the revenues and costs of a finishing and breeding sheep and beef farm.

3.3 Establishment cost per ha (k)

Establishment costs are sourced from a vineyard development model created by Fruition Horticulture Ltd. The Fruition Horticulture model provides a detailed summary of information concerning the relevant per hectare vineyard establishment costs for an investor wishing to convert land into a functioning vineyard. Fruition Horticulture's model, similar to models used in previous studies, includes the cost of the land to the investor as an establishment cost. However, land cost becomes irrelevant in this study as the assumption is made that the investor is currently the owner of a piece of land, whether it be a vineyard or a sheep and beef farm.

Table 3 provides a summary of the necessary establishment costs associated with vineyard development. It is not surprising that these costs are fairly extensive, especially considering the amount of infrastructure required. Land preparation includes earthworks and costs associated with connecting the property to water supply. Land preparation costs are typically not as extensive in Marlborough as one might have thought. This is because a lot of the land is relatively flat and access to water is fairly easy, especially in the area that is most densely populated with vineyards. The installation of necessary equipment including infrastructure (e.g. posts and wires), irrigation, planting and cultivation make up the majority of the establishment costs. Plant costs and other vineyard specific costs like mowers, crop protection and sprayers are also included.

As the investor is assumed to be currently the owner of an operational sheep and beef farm, it is a reasonable assumption that the investor has access to the required plant and machinery. It could be argued that the costs associated with land preparation may vary across subregions in Marlborough, especially in subregions that have particularly difficult terrain. However, for simplicity, in this study we assume that the land preparation costs are relatively homogeneous as farms that are particularly hard to convert to a vineyard will not do so until the profit per hectare is well above that for investors that this study is focused towards.

Vineyards do not reach a commercial production level until the vines have at least three years of growing. Therefore, in order to report an accurate estimate for the cost to establish a vineyard we must include all costs incurred during the three year waiting period. Cultivation costs are included for each of the three years as vine seedlings require constant nurturing. If the investor had not decided to convert his land he would still be generating yearly sheep and beef farm profits. Therefore, we also include three years of foregone profits as an establishment cost. The investor does, however, receive an initial cash injection from selling the existing sheep and beef stock at investment inception. Average sheep and beef stock unit prices were estimated from Beef and Lamb New Zealand's finishing and breeding sheep and beef farm survey. A sheep and beef farm typically runs about seven sheep stock units and three cattle stock units per hectare. The estimated sale prices were $120.00 for lambs and ewes, and $800 for the sale of prime cows. From Table 3 we infer the required costs associated with Marlborough vineyard establishment to be $29,879 per hectare.

3.4 Disestablishment cost per ha (l)

Finding reliable data on the costs associated with vine disestablishment proves to be more demanding. In theory, disestablishment costs include the expenses necessary to develop an existing vineyard back into an operational sheep and beef farm. Land preparation is again significant as the costs include the dismantlement of the vineyard structure and the removal of the grape vines themselves. We estimated the cost to make the land suitable for sheep and beef farming to be roughly $1000 per hectare. This is double that for vineyard land preparation but is a reasonable estimation as the costs associated with grape vine removal will be extensive. Expenses relating to fencing are fairly extensive, including installation and purchasing the necessary equipment. Local fencing contractors have provided an estimate of the labour costs associated with fencing to be roughly $20.00 per meter or $8,000.00 per fenced hectare. The study assumes that when the investor converts from a sheep and beef farm to a vineyard, the existing fencing structure becomes redundant. Therefore we include the cost to the investor of purchasing the fencing structure as a disinvestment cost. Posts and wire costs were estimated from an online sheep and beef farming forum to be $11 per meter, or $4,400 per fenced hectare. [1]

In order to convert a vineyard into an operational sheep and beef farm, the investor needs to include the costs associated with restocking the farm with sheep and beef stock units. As earlier stated, the average sheep and beef farm runs around seven sheep stock units per hectare and three cattle stock units. We assume the price to buy each stock unit to be the same as if the investor was selling his stock units, as per the when establishing the vineyard. This is a reasonable assumption as the value of the stock units required to make the sheep and beef farm operational will be roughly the same as the value of the stock that was sold when the investor converted to a vineyard. We assume it takes the investor less than one year to convert a vineyard to a sheep and beef farm. Further, the investor potentially has the ability to wait until his grapes for that year have been sold off to wineries before he converts to a sheep and beef farm. Therefore, all disestablishment costs are incurred at the disinvestment decision inception and there are no foregone vineyard profits to account for. From Table 4 the study infers the cost to disinvest a vineyard and restore a sheep and beef farm to be $16,640.

3.5 The Golden Triangle

Figure 1 plots the dataset on Marlborough vineyard transactions for the period 2007-2012. There are several observations worth noting. First, we observe that the market, pre-oversupply, is very active with 32 vineyard sales in 2007. This is particularly active when compared to the 30 transactions for 2009, 2010, and 2011 combined. This slowdown in vineyard sales, again gives supportive evidence that the oversupply issues around the time of 2008 to 2009 distressed the local wine industry and that investors may have been having second thoughts about their recent vineyard investment. However, we see that as wineries began to expand production, and the demand for grapes

[1] The study assumes that the average size of a sheep and beef paddock is one hectare

increased, the real estate market picks up again in 2012.

Second, we observe that during and after the period of distress, the per hectare value of vineyard decreased significantly. Pre-oversupply, vineyards appear to be selling for around $240,000 to $360,000 per hectare whereas post-oversupply, in 2012, the average net sale price is between $120,000 and $240,000 per hectare. This is direct evidence that people in Marlborough valued vineyard land less, during and after the oversupply period. This is not surprising considering during this period vineyard owners were dealing with a significant erosion of their revenue. We also note that in the year 2012, although the market did become significantly more active compared to the previous year, we still see the net sale price per hectare significantly lower than in 2007. This is potentially evidence that wineries in Marlborough were in fact purchasing the distressed vineyards as they caught up with local grape supply. The reason the wineries would want to purchase vineyards is clear. By owning a vineyard a winery secures grape supply and mitigates any risk associated with the future grape price. As a consequence, the local industry in now considerably more vertically integrated.

Lastly, we note the clustered nature of the observations in 2007 and 2012. On average, these maps appear to show a higher net sale price per hectare than elsewhere. The study employs these observations to generate a sample of the most valuable vineyards in the Wairau Valley subregion. The Rapaura Road area, known as the "Golden Triangle", is known for its ready water supply, fast draining soils and ability to stay relatively frost free. The research incorporates this area's characteristics with the data sourced from the Ministry for Primary Industries. Using latitude and longitudinal coordinates, this study determines whether a particular vineyard is located within or outside the Golden Triangle. With this information we calibrate our model to provide an estimate of whether vineyards located outside the Golden Triangle, on average, have a lower net sale price as a result of lower grape yield per hectare compared to those located within.

4 Results

4.1 Parameter estimates

Model parameters are calibrated to the Marlborough data in order to provide the parameters that will minimise the difference between the estimated vineyard values and the actual vineyard values. μ_ψ, σ_ψ , μ_x, δ, and GT are calibrated, whereas k and l are not as they remain fixed at $29,879 and $16,640 respectively. Table 5 presents the calibrated parameter estimates.

The estimate for μ_ψ, the drift rate of the difference in the two profit sources, is $4,202 per hectare. This appears large but is feasible given the data. Sheep and beef farm profit per hectare is relatively insignificant here as they are well outperformed by vineyards. For example, vineyard profit per hectare in 2008 is $23,312 whereas sheep and beef farm profit per hectare is only $67, making the difference between the two $23,245. This is very close to the original vineyard profit per hectare as the sheep and beef farm profit per hectare is insignificant. Even in the later years when we see vineyard profit fall to $3,230 in 2012, the vineyard model still outperforms the sheep and beef farm model by $2,770 per hectare. Therefore, the large μ_ψ is mostly caused by the drift of vineyard profits as sheep and beef farm profits have little to no effect on the stochastic process.

We also observe a large estimate for σ_ψ, the volatility of the profit difference. An estimate of $6,731 suggests that the profit difference is extremely volatile. Again, this is caused by large changes in the vineyard profit data as the sheep and beef farm data is insignificant considering the large decline in vineyard profits observed for 2008 and 2009. Evidence of this result is also present in the parameter estimate for μ_x, the drift rate of sheep and beef farm profits. An estimate of zero suggests that sheep and beef farm profit per hectare is insignificant when compared to vineyard profit per hectare.

The estimate for the discount rate, δ, of 18.65% also appears relatively high. However, given the vast difference between vineyard profits and sheep and beef profits it is realistic. The expected return on a vineyard is significantly higher than for sheep and beef farms so it is predictable that the investor discounts the sheep and beef farm by a high discount rate. The risky nature of vineyard production, as a result of changing economic conditions, is another reason why the discount rate is relatively high.

Lastly, it is interesting to observe that the estimate for GT, is very close to 1. This suggests, on average, vineyards located inside the Golden Triangle do not sell for a higher price from those located outside. There are two possible explanations to explain this anomaly. Firstly, inconsistent with local knowledge, the result shows that there is in fact no real advantage to owning a vineyard located inside the Golden Triangle. Secondly, it is possible that the Golden Triangle does in fact have superior growing conditions for grapes but that the market is not yet responding accordingly. This suggests that the vineyards located inside the Golden Triangle have been selling at a discount.

4.2 Optimal investment and disinvestment points

Table 6 presents the summary of optimal investment and disinvestment points for Marlborough vineyard investors. The investment point, ψ_H, of \$8,964 suggests that the difference between vineyard profit per hectare and sheep and beef farm profit per hectare would have to be only \$8,964 to induce vineyard investment. This is well below the required vineyard establishment costs and due to the profit difference, this optimal investment result is consistent with the actual observed behaviour of vineyard investors in Marlborough. From 2004 to 2008, the profit difference is almost always significantly greater than \$8,964. For example, in 2006 the profit difference was \$15,165. With a profit difference this high the motives for vineyard investment are clear. From Figure

1 we observe that in 2007 the market was very active, presumably as a result of lots of investors joining the market. However, as previously discussed, in recent years the profit difference has reduced considerably. The profit difference in later years is insufficient to induce investment behaviour. Figure 1 shows a good visual representation of this behaviour with very little real estate activity from 2009 to 2011. The optimal strategy for investors now is to wait and continue operations as a sheep and beef farm. However, the market becomes sufficiently more active in 2012, potentially as a result of investors becoming more optimistic about the wine industry.

Table 6 suggests that the profit difference in order to convert back from a sheep and beef farm to a vineyard, ψ_L, is equal to -\$19,720. Only a severe decline in vineyard profits or a unprecedented rise in sheep and beef farm profits would generate a profit difference this large. For example, if sheep and beef farm profit is to continue around \$200 per hectare then vineyard profits would need to decrease to -\$19,520 in order to justify converting back to a sheep and beef farm. Alternatively, if vineyard profits remained at current levels of around \$3000 per hectare, sheep and beef farm profits would need to increase to \$22,720 per hectare to make converting back rational. A rise of nearly 115 times the current average. The reason why this disinvestment point is so large and negative is because of the low average profit per hectare of sheep and beef farms when compared to vineyards, and the extensive costs associated with farm establishment. Although large in scale, this result does appear consistent with local vineyard investors. Vineyard profit has decreased largely since the oversupply issue, however very few investors have converted vineyard operations back into sheep and beef farms as the difference between the two profit sources is still well above the optimal disinvestment point.

Figure 2 plots the optimal investment and disinvestment profit differences. As stated earlier, $V_0(\psi)$ represents the value of the non-active vineyard with the investor currently operating a sheep and beef farm with the option to convert operations into wine grape production. As the profit difference increases we see the value of the option to convert to a vineyard increase. The investor waits until the profit difference is at least $8,964, and then pays the required vineyard establishment costs, k, in order to convert to a vineyard. The investor then continues to produce wine grapes until the profit difference becomes largely negative, in which case he pays the required disestablishment costs, l, in order to convert back to a sheep and beef farm.

5 Conclusions

In little over thirty years, Marlborough has developed into New Zealand's largest wine producing region. The seemingly hasty expansion of the local viticulture industry has caused many alternative farm types, in particular sheep and beef farms, to convert to wine grape production. Oversupply issues have since put pressure on the industry, causing a significant erosion of the average grape price directly resulting in a narrowing of vineyard profit margins. As a consequence, vineyards are now selling for considerably less. The local industry is increasingly more vertically integrated as wineries continue to purchase distressed vineyard.

The intension of this study was to provide insight into the effect that changing economic conditions have on Marlborough vineyard investment decisions. In particular, this research provides a tractable framework of the analysis of optimal investment and disinvestment for Marlborough vineyard investors. Extending the traditional real options framework, this study develops a technique that accommodates for the consideration of the stochastic nature in profits of alternative farm types, an important determinant of the investment/disinvestment decision. Specifically, this study assumes that the vineyard investor is potentially the owner of an existing Marlborough sheep and beef farm. The research provides an empirically calibrated model that allows investment and disinvestment trigger points simulating optimal investment behaviour for vineyard investors, a potentially valuable tool given the importance of the viticulture industry, both locally and nationally.

The empirical results successfully show consistency with the behaviour of Marlborough vineyard investors. This research presents optimal investment occurs when the difference between vineyard profit and sheep and beef farm profit is well below the historical average. However, with the recent decline in vineyard profit the result suggests that, given the current economic conditions, investors with the option to convert sheep and beef farm land into vineyard should defer investment. The result also provides an optimal disinvestment point. In order to generate disinvestment, the profit difference would need to become sufficiently negative in order to cover the necessary costs of conversion. When looking specifically at vineyard location, this study finds there is no advantage to vineyard land located within different subregions of Marlborough. This anomaly is inconsistent with local knowledge.

This analysis assumes that the difference in two geometric Brownian motion stochastic processes evolves according to an arithmetic Brownian motion. Although this allows sheep and beef farm profits to exceed vineyard profits by arbitrary amounts, the assumption may not hold true. Through a possible extension, solving a two stochastic component model numerically could potentially prove to be very useful. The assumption that the difference in two geometric Brownian motions follows an arithmetic Brownian motion would be removed, at the cost of computational intricacy. Further, the use of micro level data is another potential extension. Using aggregated data allows the study to determine investment and disinvestment trigger points across the entire Marlborough region. However, when explaining individual investment behaviour the micro level data becomes particularly relevant. It is possible that the change in vineyard values across subregions would be more pronounced in this type of study.

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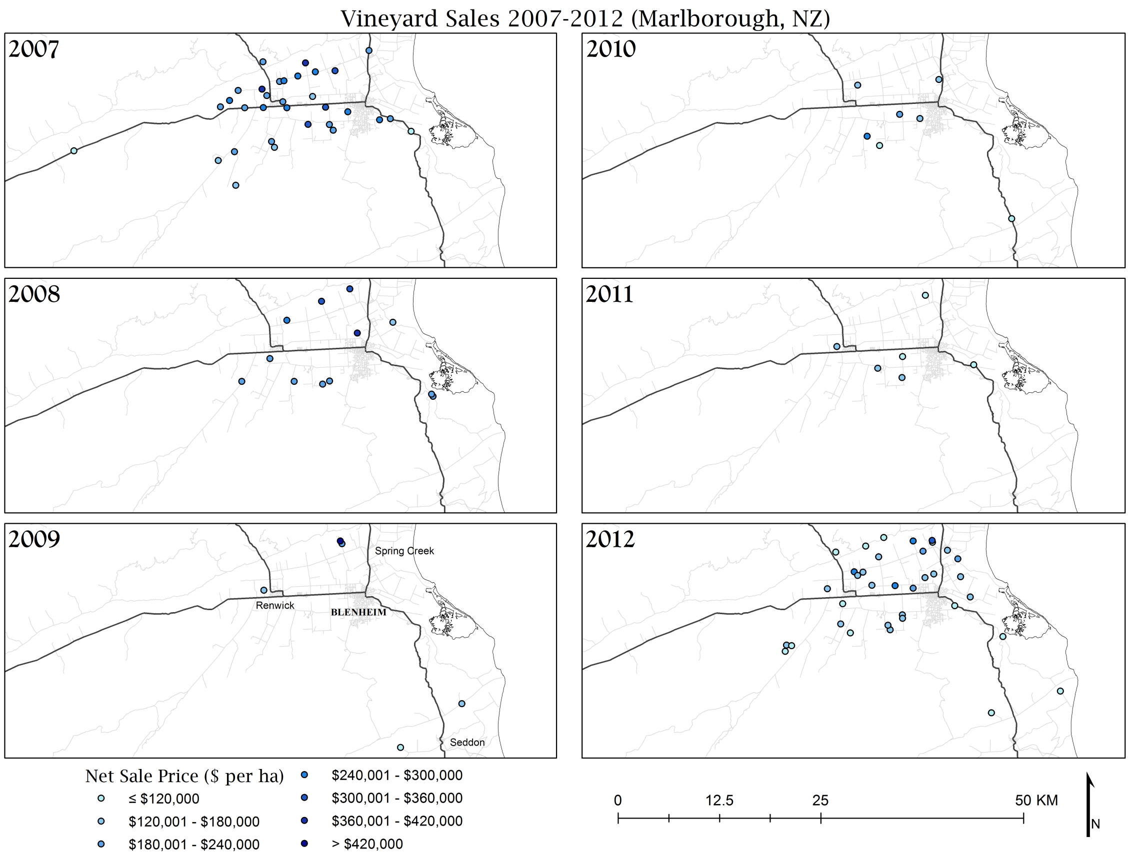

Figure 1: Net sale Price ($ per ha)

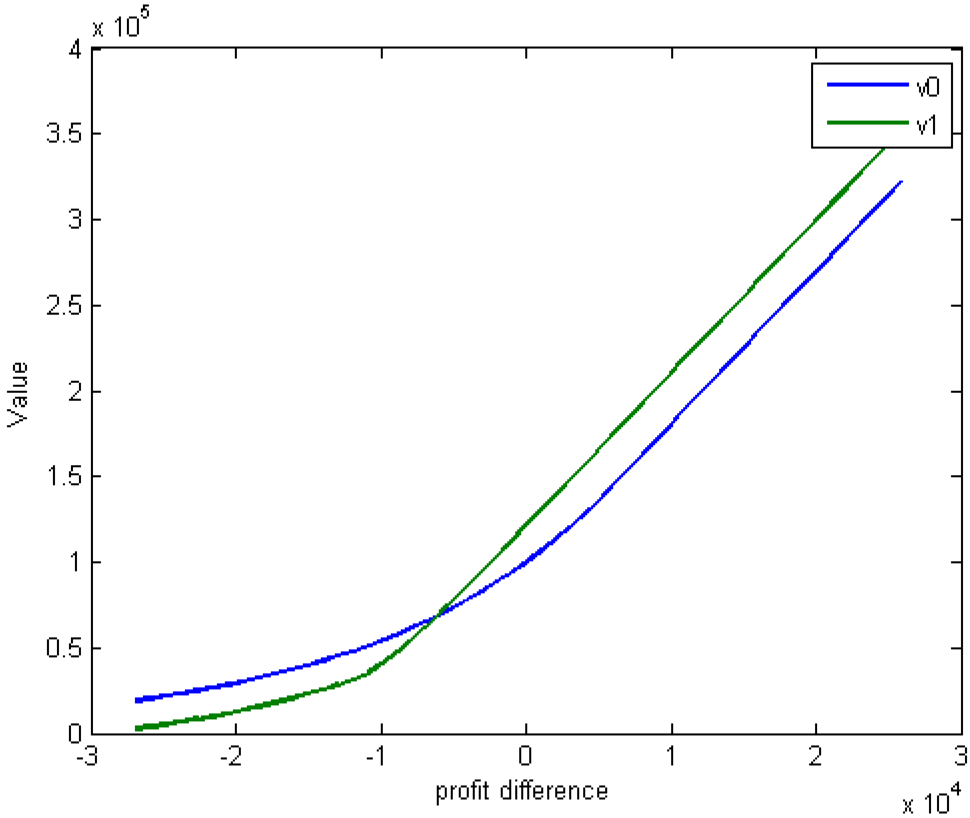

Figure 2: Value functions

Table 1: Marlborough vineyard model profit \$/ha (y)

Year	Producing area (ha)	Profit before tax	Profit before tax per ha
2004	21.00	215,700	10,271
2005	23.00	176,270	7,664
2006	23.00	350,060	15,220
2007	25.00	417,020	16,681
2008	27.00	629,420	23,312
2009	29.00	108,070	3,727
2010	30.00	55,730	1,858
2011	30.00	167,300	5,557
2012	30.00	96,900	3,230

Table 2: Canterbury/Marlborough finishing and breeding sheep and beef model profit \$/ha (x)

Year	Producing area (ha)	Profit before tax	Profit before tax per ha
2004	426.00	49,868	117
2005	426.00	49,868	117
2006	480.00	26,262	55
2007	480.00	23,990	50
2008	464.00	30,995	67
2009	469.00	58,693	125
2010	469.00	46,615	99
2011	475.00	111,496	235
2012	478.00	220,039	460

Table 3: Establishment cost \$/ha (k) for converting a farm into a vineyard

Item	Year 1	Year 2	Year 3	Total
land preparation	500	-	-	500
structure	9,652	-	-	9,652
irrigation	3,889	-	-	3,889
cultivation	900	900	900	2,700
plants and associated costs	9,259	-	-	9,259
crop protection	3,000	-	-	3,000
foregone sheep and beef farm profit	1,373	1,373	1,373	4,119
less sheep stock sale revenue	840	-	-	840
less cattle stock sale revenue	2,400	-	-	2,400
total establishment cost per ha (k)				29,879

Table 4: Disestablishment cost \$/ha (l) for converting a vineyard into a farm

Item	Year 1
land preparation	1,000
fencing labour	8,000
fencing structure	4,400
plus sheep stock purchases	840
plus cattle stock purchases	2,400
total disestablishment cost per ha (l)	16,640

Table 5: Summary of parameter estimates

Parameter	Estimate
μ_ψ	4202.30
σ_ψ	6730.70
μ_x	0.0000
δ	0.1865
k	29879
l	16640
GT	0.9999

Table 6: Critical investment and disinvestment points

Parameter	Estimate
ψ_H	8964
ψ_L	-19720