A Real Options Approach To Evaluating Agricultural Investments Under Uncertainty: When To Get In And Out Of Sugarcane Production

Marcus Smith

PhD, Adjunct Lecturer, College of Business, Law and Governance, James Cook University, Australia

Abstract

This case study presents an application of the Real Options approach to evaluate a farming enterprise under sugarcane in the lower Herbert district of north Queensland, Australia. It demonstrates how this approach may be used to calculate the value of a farming enterprise using real-world data as well as the critical prices at which it is optimal for the farm operator to exercise managerial options in order to maximise the value of their investment. In practical terms, this information is useful to assist farmers to make optimal decisions regarding whether or not to plant their field crops for the current season and at which price it is worth considering alternative uses for their crop land, such as rotating their crops or converting their land for other industrial uses.

Results of the case study indicate that the value of the 99.25 ha cane enterprise in 2011-12 sugar prices was $1,380,000, which amounts to $13,904 per hectare ($5,629 per acre), and the average value of the enterprise over the period 1998-99 to 2011-12 was $762,500, which amounts to $7,683 per hectare ($3,110 per acre). The critical price at which to cease farming operations is shown to be $15.75 per tonne of cane (IPS sugar price of ~$188/t), while the price at which to recommence operations is $24.14 per tonne of cane (IPS sugar price of ~ $286/t). A significant finding from the case study is that the critical price to abandon sugarcane production on a previously decommissioned cane farm turned out to predict remarkably well a period of low sugar prices during which sugarcane growers within neighbouring districts actually exercised their option to exit the industry and the land was converted to managed-investment forestry schemes.

Keywords: real options analysis, agricultural evaluation, asset value, investment decisions, sugarcane production.

JEL Classification: G11, G12, G13, G31, G32.

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1. Introduction

Finding profitable investment opportunities is the key objective of capital budgeting and evaluating those investments under uncertainty is a well-known problem of central importance in financial economics (Cortazar & Schwartz, 1993). This is a particularly salient issue while one is attempting to establish a fair price for agricultural farm enterprises, which is typically only determined in accordance with infrequent, localised real estate sales. From a financial-economic perspective, however, the traditional and most widely applied technique for valuing investment opportunities is the Discounted Cash Flow (DCF) method (Schwartz & Trigeorgis, 2004). This method involves calculating the present value of an expected cash flow stream over a predetermined investment horizon and, in the case of investments in long-term assets, is often assigned a terminal asset value to take into account future cash flows in perpetuity.

The known difficulties associated with using conventional valuation methods such as DCF analysis to value risky investment opportunities are well documented (see, for example, Brennan & Schwartz, 1985; Kelly, 1998; Cortazar, Schwartz, & Salinas, 1998; Duku-Kaakyire & Nanang, 2002; Colwell, Henker, & Ho 2003; McNamara, 2003; Schwartz & Trigeorgis, 2004). In particular, the DCF method is widely criticised for being poorly equipped to deal with the stochastic nature of output prices and its inability to capture value created by the strategic capacity of management to respond operationally to output price volatility over the life of an investment (Brennan & Schwartz, 1985). As a consequence of its relative simplicity, the DCF valuation method is particularly difficult to apply to assets that operate in markets which exhibit high levels of uncertainty (Cortazar & Schwartz, 1993). DCF valuations are most accurate when the risk is zero or relatively minimal and the future cash flows of the asset are assumed to be known with certainty – such is the case for government bonds and discount securities. However, these ideal conditions are typically not synonymous with the riskier business conditions faced by real firms.

Real options approaches to evaluating investment opportunities are heralded as significant theoretical developments in financial economics (Schwartz & Trigeorgis, 2004). Using these approaches, the managerial flexibility to react to new information and the management of uncertainty in future conditions confer significant value to an investment (Trigeorgis & Mason, 1987; McNamara, 2003). The economic foundation of the Real Options approach is based on the condition that desirable payoff patterns can be replicated and evaluated via a portfolio of transactions involving market-traded assets (Trigeorgis & Mason, 1987). Where the returns of the portfolio replicate the payoffs of an investment opportunity in all states of the world, the portfolio and the opportunity must have the same market price in the absence of arbitrage opportunities (McNamara, 2003).

Seminal developmental work in the area of evaluating natural resource investments using option pricing was produced by Brennan and Schwartz (1985) who derived a continuous-time model that evaluates investment opportunities as real options over the underlying commodity. There are a number of advantages in using this option pricing evaluation framework when valuing risky investments (such as natural resource assets) instead of the conventional DCF analysis. First, the Real Options approach explicitly accounts for risk to the future cash flow stream using a systematic, market-based approach to deal with output price uncertainty. Second, using this approach obviates the need to assign a risk-adjusted discount rate generated from a market equilibrium model (such as the Capital Asset Pricing Model). Third, the model allows one to determine the critical output prices at which it becomes optimal to exercise various operational policies over the life of the asset.

There are few published examples of empirical studies within the financial-economics literature that provide detailed implementations of the seminal model of Brennan and Schwartz (1985). Furthermore, despite the conceptual advantages that this model offers over traditional valuation methods, practitioners in the finance industry have generally not adopted the model for practical use[1]. A possible reason for this is the complexity in developing implementations of this model. It is acknowledged that, in stark contrast to the DCF method, it is exceedingly difficult to develop (and implement) an algorithm that can solve the Brennan and Schwartz (1985) model numerically under general conditions (see, for example, Kelly, 1998; McNamara, 2003).

Notwithstanding these difficulties, a Renewable Resource Model (RRM) (Smith, 2012) was developed using the Brennan and Schwartz framework to evaluate renewable resource assets. In departure from the Brennan and Schwartz (1985) modelling that was specifically developed to evaluate investments in natural resource assets such as mines, the RMM is recast to suit investments in assets that have a continuously renewable (or indeed infinite) resource inventory. A suitable application of the RRM does not necessarily require that the underlying resource be replenished on an annual basis due to natural processes (which ideally could be considered an infinite resource); it is equally applicable to cases where levels of a physical resource inventory may be maintained annually by the managers of the asset, such as in the case of perennial cropping.

There is a growing literature of Real Options applications that evaluate agricultural investments, which includes soybean processing (Plato, 2001), tart cherry production (Nyambane & Black, 2004), organic wheat and barley production (Ehmke, Golub, Harbor, & Boehlje, 2004), hog production (Odening, Mußhoff, & Balmann, 2005), dairy operations (Engel & Hyde, 2003; Tauer, 2006), coffee planting (Luong & Tauer, 2006), cotton farming (Seo, Segarra, Mitchell, & Leatham, 2008), citrus operations (Iwai, Emerson, & Roka, 2009) and livestock farms (Bartolini, Gallerani, & Viaggi, 2010). Among these applications, many types of real options are analysed. Examples of these applications include the decision to replace existing manual operating systems with automatic systems (Engel & Hyde, 2003), evaluating optimal orchid replacement policies (Nyambane & Black, 2004), adoption of more efficient irrigation technology (Seo et al., 2008) and deciding when it becomes optimal to change from conventional production to organic production (Ehmke et al., 2004).

This work contributes to this growing literature by presenting a case study application of the RRM to evaluate a sugarcane farming enterprise in the lower Herbert district of north Queensland, Australia. Sugarcane production has been the predominant agricultural industry for coastal Queensland since the middle of the 19th century and today remains the economic backbone of many coastal communities (Smith, Poggio, Thompson, & Collier, 2014). In particular, this case study demonstrates how the RRM may be used to calculate the value of the farm enterprise using real-world data as well as the critical prices at which this particular cane grower should exercise various managerial options in order to maximise the value of their farm. These critical prices are useful to farmers to help them decide whether or not to plant their field crops for the current season and at which price it is worth considering alternative uses for their crop land, such as rotating their crops or converting their land for other industrial uses.

[1] Grafstrom & Lundquist (2002) suggest that a general reason why practitioners rarely use the real options method is due to the trouble with unpacking complexities within the approach and, in turn, explaining the results to clients.

2. The renewable resource model

The RRM calculates the present value of the cash flows of an asset based on a continuous arbitrage free position between the investment opportunity itself and a self-financing portfolio of risk-free bonds and future contracts over the underlying commodity. The mathematics of the Wiener process is used in conjunction with Ito's Lemma (a mathematical technique for differentiating and integrating functions of continuous-time stochastic processes[1]) to derive the total differential of a function of stochastic variables. The resulting set of second order differential equations of the RRM value the asset based on the current spot price, the volatility of the spot price, the real risk-free rate, the convenience yield of the commodity and various operational cost parameters. The model assumes that all prices increase uniformly at the same rate of inflation to exclude time (*dt*) as a state variable, which implies that there is no uncertainty and all parameters are constant. The RRM is written as the following system of equations:

$$\frac{1}{2}\sigma^2 s^2 \frac{d^2 v}{ds^2} + (r-\kappa)s\frac{dv}{ds} + q(s-a) - \tau - (r+\lambda_1)v = 0 \text{ (value of operational asset, } v(s)\text{)} \quad (1)$$

$$\frac{1}{2}\sigma^2 s^2 \frac{d^2 w}{ds^2} + (r-\kappa)s\frac{dw}{ds} - f - (r+\lambda_0)w = 0 \text{ (value of decommissioned asset, } w(s)\text{)} \quad (2)$$

where, $\tau = t_1 qs + t_2 q(s(1-t_1)-a)$ (tax function); $r = ((1+\rho)/(1+\pi))-1$ (real risk-free interest rate).

Subject to the boundary conditions:

$$w(s_0) = 0 \text{ (optimal price to abandon a previously decommissioned asset)} \quad (3)$$

$$v(s_1) = w(s_1) - k_1 \text{ (optimal price to cease operations)} \quad (4)$$

$$v(s_2) = w(s_2) + k_2 \text{ (optimal price to recommission operations)} \quad (5)$$

$$v_s(s_1) = w_s(s_1) \text{ (smoothing condition over operational transition point to close)} \quad (6)$$

$$v_s(s_2) = w_s(s_2) \text{ (smoothing condition over operational transition point to open).} \quad (7)$$

The RRM is based upon the Brennan and Schwartz (1985) model, which consists of two differential equations that describe the value of a mine in an open and closed state and a set of boundary conditions that determine the optimal operating policy (i.e. to open, close or abandon). Since current levels of production do not impact on future production capacity in the case of a renewable resource, the functional dependence of the asset's value on the quantity of reserves -qv_q has been removed from the original equations[2]. Furthermore, the boundary conditions have been modified to remove embedded discontinuities and discontinuous behaviour to ensure the RRM functions are smooth and continuous over their entire range of prices. The conceptual framework of the RRM is illustrated in Figure 1, which is essential to understanding and interpreting the outputs from the model.

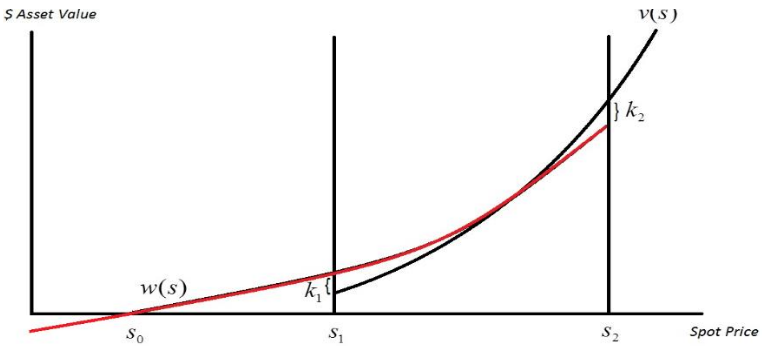


Figure 1. Conceptual framework of the RRM and its critical prices[a]

Notes: [a] Adapted from Brennan and Schwartz (1985).

[1] Ito's Lemma is analogous to taking the limit of a Taylor series style expansion, where in the limit of the infinitesimal process, the higher than second order terms disappear.

[2] In the case of an asset with a renewable (or indeed infinite) inventory, as the quantity of reserves $Q \to \infty$ this implies that the term $-qv_Q \to 0$ resulting in the Q-dependence disappearing.

Figure 1 depicts the value of an asset currently being operated that is derived along the function *v(s)* (black curve), while the value of the decommissioned asset is derived along the function *w(s)* (red curve). Accordingly, it is optimal to operate the asset until prices fall to s_1, at which price the value of the operational asset is equivalent to the value of the decommissioned asset less the cost of closing down operations, k_1. This may be interpreted as the cane price at which the farmer should reconsider planting for the next season and/or harvesting for the current season, whilst maintaining the cane land until prices improve. If the asset is currently not operational, it is not appropriate to outlay funds to begin/resume production until the price rises to s_2, at which price the value of the operational asset is equivalent to the value of the decommissioned asset plus the cost of reinstating operations, k_2. s_0 represents the critical price at which the value of the asset is zero and may be interpreted as the cane price at which to abandon a currently nonoperational cane farming enterprise.

The general solution to the RRM is derived analytically and comprises the following closed-form solutions (Smith, 2012):

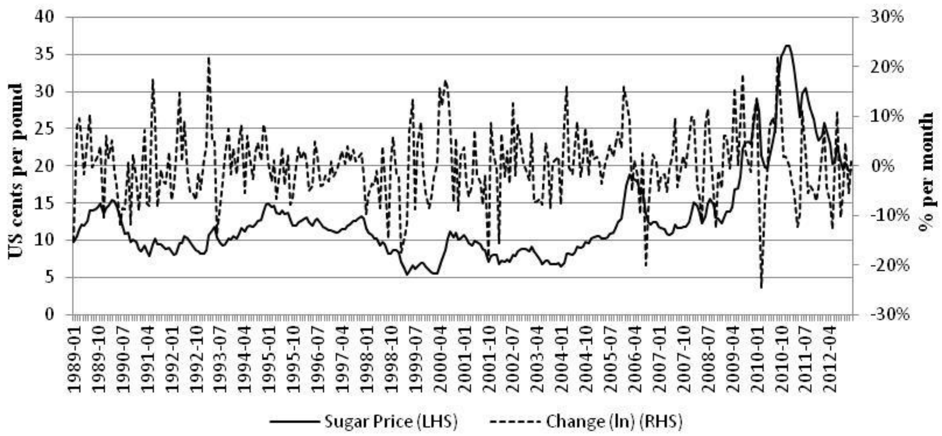
$$v(s) = c_1 s^{n_1} + \frac{q(1-t_1)(1-t_2)}{(\kappa + \lambda_1)} s - \frac{qa(1-t_2)}{(r+\lambda_1)} \text{ (for the operational asset);} \tag{8}$$

$$w(s) = c_0 s^{n_0} - \frac{f}{r+\lambda_0} \text{ (for the temporarily decommissioned asset);} \tag{9}$$

where c_0 and c_1 are constants of integration determined by substitution of Equations (8) and (9) into the boundary conditions outlined in Equations (3) to (7), while n_0 and n_1 represent the exponential change in value of the asset with respect to the spot price, *s*. The development of a numerical algorithm and the implementation of that solution procedure in a computerised system are presented in Smith (2012).

3. Parameters for the case study

The Intercontinental Exchange No. 11 (ICE No 11) futures market is the world benchmark for determining the value of raw sugar and the most commonly used mechanism to derive the Australian sugar price (Queensland Sugar Limited, 2012). Figure 2 illustrates monthly futures sugar prices (LHS) as well as the volatility in this price series (RHS) over the period January 1989 to December 2012.



Notes: [a] United States Department of Agriculture, 2013. (Original prices sourced from New York Board of Trade; Contract No. 11- f.o.b. stowed Caribbean port, including Brazil, bulk spot price, plus freight to Far East).

Figure 2. ICE Contract 11 average monthly futures sugar prices[a], January 1989 – December 2012

A key assumption of the RRM is that the only source of uncertainty is the future volatility in the price of the underlying commodity. The spot price is explicitly modelled as a continuous stochastic process in which the logarithm of the randomly changing quantity follows standard geometric Brownian motion with drift:

$$dS = S\mu dt + S\sigma dz$$

$$\frac{dS}{S} = \mu dt + \sigma dz \tag{10}$$

where $\frac{dS}{S}$ is the rate of change (rate of return), μ is the local trend (drift), σ is the instantaneous standard deviation, and dz is an increment to a Wiener process.

The first term in the stochastic process described by Equation (10) captures the expected value (drift), while the second term captures the deviation away from this expected value at any point in time due to the random walk that the price is assumed to follow. A data series that follows a random walk must typically be differenced once to obtain stationarity[1], and is thus referred to as an integrated series with an order of integration of one (Griffiths, Carter Hill, & Lim, 2012). An Augmented Dickey-Fuller test was performed over the monthly price series January 1989 to December 2012, which provided 288 observations (see Appendix 1). The null hypothesis that the *sugar price is nonstationary* could not be rejected since the absolute value of the calculated Dickey-Fuller test statistic is less than the 5% critical value (2.452<2.871; p = 0.1285). However, we reject the null hypothesis that the *first difference of the sugar price is nonstationary* since the absolute value of the test statistic is greater than the 5% critical value (11.070>2.871; p = 0.0000).

Using the monthly data series for contract #11 futures sugar prices from January 1989 to December 2012, the statistic $d_t = \ln(\frac{s_{t+1}}{s_t})$ is calculated resulting in a mean of 0.0019, variance rate of 0.0053 and standard deviation of 0.0725. Annualising these calculations by multiplying by 12 gives an annually adjusted mean 0.0228 and variance of 0.0631, which implies an annualised sugar price volatility of ~25.12%. To put this into perspective, annual price swings of between 25 to 40 per cent are commonly observed in natural resource industries (Brennan & Schwartz, 1985).

The returns to the replicating portfolio depend on the deterministic relationship that exists between spot and future prices of the underlying commodity. In the absence of arbitrage opportunities, this relationship is characterised by the following equality:

$$F_{t,T} = S_t e^{(\rho-\kappa)(T-t)} \tag{11}$$

where, $F_{t,T}$ is the future price of the commodity; S_t is the current spot price; e^i is the exponential compounding function; κ is the net convenience yield; ρ is the nominal risk-free rate of return; and, $(T-t)$ is an increment of time to maturity.

ρ is the nominal annual risk-free interest rate, which represents the opportunity cost of the funds tied up in holding the physical commodity. The conventional approach when using real option pricing is to use the rate of return on government securities as a proxy for the risk-free interest rate[2].

The convenience yield is defined as a measure of the benefits or flow of services that accrue to the holder of physical inventories of a commodity that do not accrue to the owner of a futures contract over those inventories (Brennan & Schwartz, 1985; Grafstrom & Lundquist, 2002; McNamara, 2003). For example, because a contract for the future delivery of a commodity like sugar cannot be used at present for productive purposes, it is therefore unlikely to be regarded the same way by a manufacturer who uses sugar as an input within the production process. It is rational to assume that commercial holders of commodities will continue to build up their inventories until the point where the marginal convenience yield is equal to the opportunity cost of the funds tied up in the inventory.

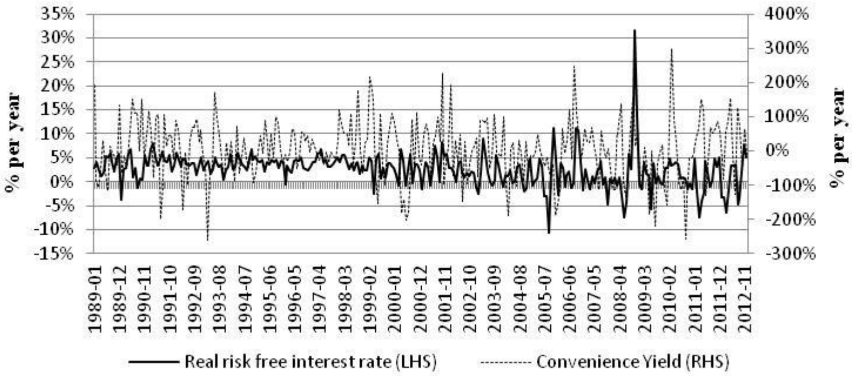
A high convenience yield implies that the benefits of holding inventory are greater than the costs of storage and carry when there is low availability in the market. Holding inventory provides economic benefits during periods when demand increases and stocks become relatively low, thus the value of the option to delay investment decreases. For instance, holding inventories negates the problems of delays in production and supply and enables the firm to take advantage of unexpected spikes in demand (McNamara, 2003). Conversely, high levels of inventory result in a low convenience yield. As the convenience yield decreases or becomes negative the value of the option to delay investment in inventories increases.

[1] A nonstationary data series is characterised by wandering behaviour around a constant and/or trend, while stationary data is characterised as fluctuating around a constant and/or trend (Griffith et al., 2012).
[2] See, for example, Schwartz & Trigeorgis, 2004.

The average annualised convenience yield is calculated to be 3.03% by rearranging Equation (11) and using the market yield on United States Treasury securities at 10-year[1] constant maturity (quoted on an investment basis) as a proxy for the risk-free rate of return together with the sugar price series as follows:

$$\kappa = \rho - \frac{1}{\Delta t} * \ln\left[\frac{F(T)}{S(t)}\right]. \tag{12}$$

The average annualised real risk-free rate of return over the period January 1989 to December 2012 was calculated to be 2.66 %. This calculation is based on deflating the nominal risk-free rate by applying the Fisher equation[2] using annualised changes in the US Consumer Price Index[3] over the corresponding time period. Figure 3 graphs the time series calculations of the risk-free interest rate and convenience yield.



Notes: [a] 10-year US Treasuries interest rate data sourced from Board of Governors of the Federal Reserve System (2014).
[b] Consumer Price Index data sourced from United States Department of Labor (2013).

Figure 3. Annualised real risk-free rate and convenience yield, January 1989 – December 2012[a,b]

Production data was sourced from the operator of a cane farm in the lower Herbert district of north Queensland (Smith, Telford, Poggio, & Larard, 2013). This data was then entered into the Farm Economic Analysis Tool (FEAT) (Cameron, 2005) to calculate production costs and the equivalent price per tonne of cane. FEAT is computer program written specifically for evaluating cane farm enterprises that was developed under the Queensland Government FutureCane initiative (see Queensland Government Department of Agriculture and Fisheries, 2013).

q represents the annual rate of production, which is the average number of tonnes of sugarcane produced per year on the cane land. Estimates of historical production averages were obtained from the farm operator for each of the various stages of the sugarcane crop cycle, which consists of a plant crop, 4 subsequent ratoon crops and a bare fallow. The level of cane production is directly related to biophysical factors including soil type, rainfall and climatic variables, as well as enterprise characteristics such as farm size and operating strategy, capital and labour constraints, and the farmer's management objectives (see, for example, Smith et al., 2014).

a is the average annual cost of production per tonne of cane (i.e. total farming costs divided by average cane production) and is incurred only when the farm is in an operating state. Conversely, f is the annual periodic maintenance cost (i.e. fixed costs) for a farm where sugarcane production has been decommissioned temporarily due to prices being too low to warrant the outlay of the variable costs of production. The transition cost, k_1, represents the cost of decommissioning operations on the farm, which may include relevant redundancies, outstanding general liabilities and termination payments on current contracts. On the other hand, k_2 represents the transition cost of reinstating operations on a previously decommissioned farm, which may include hiring and training costs, miscellaneous costs such as uniforms as well as other general reinstatement costs. These costs were not provided by the operator. In acknowledging that the operator is likely to incur expenses to transition between each operational state, an arbitrary value of $10 000 is assigned for the k_1 and k_2 transition costs.

[1] The data series for the nominal US 10-year annual bond yield was sourced from Board of Governors of the Federal Reserve System (2014). The annual yield on US Treasuries with a 10-year constant maturity is used given the long-term nature of the investment.
[2] Fisher's well-known equation for approximating the relationship between nominal and real interest is $1+\rho = (1+r)(1+\pi)$.
[3] The US consumer price index data series was sourced from US Department of Labor (2013).

t_1 represents the royalty rate, while t_2 denotes the corporate income tax rate. Property taxes are levied based on the value of the cane land regardless of its present operational state, where λ_0 and λ_1 are the proportional rates of property tax levied on the decommissioned and operating farm, respectively. The operational parameters for the cane farm are summarised in Table 1.

Table 1. Farm-specific operational parameters for the case study

Parameter	Value
Farming area (hectares/acres)[a]	99.25 ha / 245.25 acres
Average annual cane production (tonnes)[a]	7,311 tonnes
Average annual production rate [a] (t/ha)	88 t/ha
Plant (t/ha)	100 t/ha
1st ratoon (t/ha)	105 t/ha
2nd ratoon (t/ha)	94 t/ha
3rd ratoon (t/ha)	75 t/ha
4th ratoon (t/ha)	68 t/ha
Average relative commercial cane sugar (CCS)[a]	13.5
Total annual cost (excl. state and income taxes)[a]	\$189,233
Fixed (maintenance costs)	\$33,546
Variable costs	\$155,687
Average production costs (\$/t)	\$25.88
Property taxes [b]	~1.5%
Less than \$350,000	Nil
\$350,000 or more but less than \$2.25M	\$1,450 plus 1.7c for each \$ >\$0.35M
\$2.25M or more but less than \$5M	\$33,750 plus 1.5c for each \$ >\$2.25M
\$5M or more	\$75,000 plus 2.0c for each \$ >\$5M
Australian corporate tax rate[c]	30%
Royalty rate	-
Current cane price (\$/t)[d]	\$34.75
Cost to decommission operations	\$10,000
Cost to commence/reinstate operations	\$10,000

Notes: [a] Farm production data sourced from Smith et al. (2013). Average production rate of farm area under sugarcane excluding fallow area.
[b] Section 32(1)(b) of the Land Tax Act 2010. (The State of Queensland, 2014).
[c] Australian corporate tax rate, 2014. (Australian Taxation Office, 2014).
[d] Price per tonne of cane calculated using sugar pricing formula for Herbert River mill area: [(0.009*IPS)*(relativeCCS-4)+(constant)+(bonuses)-(levies)], Smith et al. (2013). The cane price is based on IPS (International Polarity Scale) prices as used for the measurement of raw sugar (ABARES, 2014).

4. RRM cane farming enterprise valuation

The case study parameters were entered into the RRM to evaluate the cane farming enterprise and determine the critical prices at which it is optimal to exercise various managerial options. The full list of input parameters as well as the RRM evaluation are summarised in Table 2 (The RRM output screen is provided in Appendix 2.)

Table 2. RRM input parameters and results summary

Variable/ Parameter	Description	Value
s	Current equivalent price for cane (\$/tonne of cane)[a]	34.75
r	Average real risk-free rate (%/yr)[b]	2.66
K	Average convenience yield (%/yr)[b]	3.03
σ^2	Variance rate[c]	0.0631
q	Annual rate of production (tonne of cane/yr)[d]	7,311
a	Average annual cost of production (\$/tonne of cane/yr)[d]	25.88
f	Annual maintenance cost (\$/yr)[d]	33,546
t_1	Royalty rate (%)	nil
t_2	Income tax rate (%)[e]	30
λ_1	Property tax rate operational asset (%)[f]	1.5
λ_0	Property tax rate decommissioned asset (%)[f]	1.5
k_1	Cost to decommission operations (\$)	10,000
k_2	Cost to commence/reinstate operations (\$)	10,000
$v(s)$	Value of operational asset at current equivalent cane price (\$)[a,g]	1,380,000
$w(s)$	Value of decommissioned asset at current equivalent cane price (\$)[g]	N/A
$H(s)$	Current value of cane farm enterprise (\$/ha/acre)	13,904 / 5,629
$H(s)_{ave}$	Average value of cane farm enterprise 1989-90 to 2011-12 (\$)	762,500
$H(s)_{ave}$	Average value of cane farm enterprise 1989-90 to 2011-12 (\$/ha/acre)	7,683 / 3,110
s_1	Optimal price to temporarily decommission operations (\$/tonne of cane)[g]	15.75
s_2	Optimal price to commence/reinstate operations (\$/tonne of cane)	24.14
s_0	Price at which cane farm enterprise value is zero (\$/tonne of cane)	19.77

Notes: [a] Equivalent price per tonne of cane is computed using the FEAT (Smith et al., 2013) and is net of levies. The cane price is based on IPS (International Polarity Scale) prices as used for the measurement of raw sugar (ABARES, 2014).
[b] Computed using data sourced from: United States Department of Agriculture (2013); US Department of Labor (2013); and, Board of Governors of the Federal Reserve System (2014).
[c] Computed using ICE Contract 11 futures sugar prices sourced from United States Department of Agriculture (2013).
[d] Farm production data sourced from Smith et al. (2013).
[e] Property tax rates sourced from The State of Queensland (2014).
[f] Australian corporate tax rate (Australian Taxation Office, 2014).
[g] Asset is currently operational given that the equivalent cane price is currently higher than the critical price, s_1.

The results presented in Table 2 may be interpreted as follows. Given that the current price of $34.75 per tonne of cane is above the critical price of $15.75 (i.e. optimal price at which to decommission operations), the optimal managerial policy for the cane land is operational. In an operating state, the RRM values the cane farming enterprise at $1,380,000 in 2011-2012 cane prices, which is equivalent to $13,904 per hectare or $5,629 per acre. Figure 4 presents the full range of the RRM values (in millions of dollars along the vertical axis) as a function of the cane price (in terms of dollars per tonne of cane across the horizontal axis).

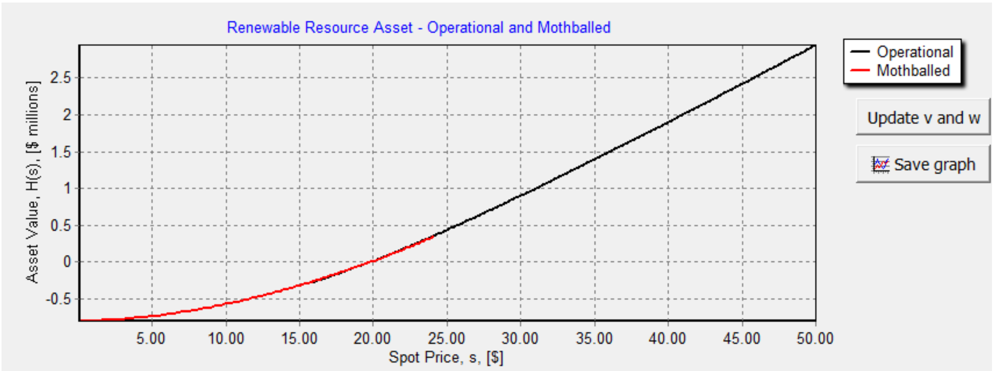
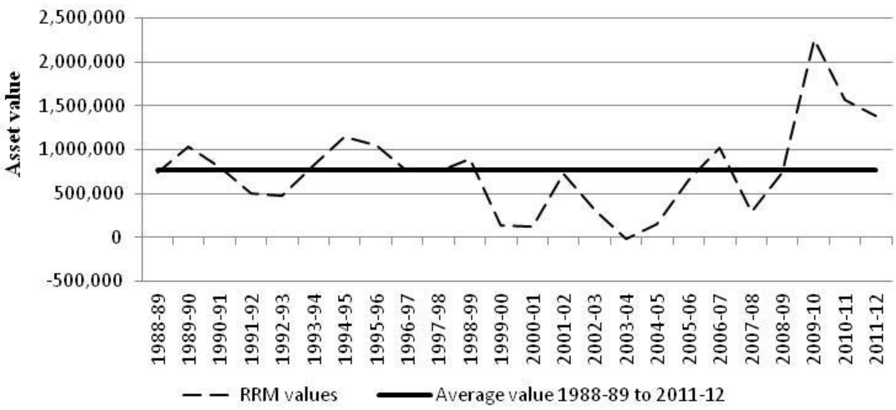


Figure 4. RRM valuation of cane farming enterprise as a function of the cane price

The RRM functions in Figure 4 show the value of the sugarcane farming enterprise at any given price, per tonne of cane. It is important to note that this cane price is derived from the world sugar price, which is assumed to follow a random walk and may change instantaneously in the futures markets. However, in a practical sense, land values for farming enterprises are determined by market orders (i.e. bids and offers) in real estate markets that typically lack depth, breadth and resilience in comparison to futures markets. It follows that since key parameters such as the price volatility, the average risk-free rate and average convenience yield applied in the RRM evaluation were calculated using annualised data over several decades (i.e. 1989 to 2012), the average value calculated from historical prices over this period is more likely to represent a fair market price for the cane farming enterprise rather than a value determined at any one particular point in time. Accordingly, Figure 5 plots RMM calculations of value of the cane farming enterprise at historical prices in relation to the average value over the period 1988-89 to 2011-12, which is calculated to be $762,500 or $7,683 per hectare ($3,110 per acre).



Note: [a] Equivalent prices per tonne of cane are computed using FEAT (Cameron, 2005). Cane prices are based on IPS (International Polarity Scale) prices as used for the measurement of raw sugar (ABARES, 2014).

Figure 5. RRM asset values at historical cane prices[a]

5. Calculations for critical prices at which to exercise managerial options

The critical prices produced from the RRM lay out the optimal operating conditions for the cane farming enterprise. The results of the RRM calculations for the critical option prices ($/tonne of cane) are listed as follows:

- s_1 = $15.75 per tonne of cane (IPS sugar price ~$188/*t*) – optimal cane price to temporarily decommission cane production on an operating farm;
- s_2 = $24.14 per tonne of cane (IPS sugar price ~$286/*t*) – optimal cane price to begin/reinstate cane production on a previously decommissioned farm; and,
- s_0 = $19.77 per tonne of cane (IPS sugar price ~$235/*t*) – optimal cane price at which to abandon a previously decommissioned cane farm; cane price at which decommissioned cane farming enterprise value = 0.

The critical prices s_1, s_2 are analogous to exit and entry values, respectively. In practical terms, these calculations may be used to assist farmers to make optimal decisions regarding whether or not to plant their field crops for the current season and at which price it is worth considering alternative uses for their crop land, such as rotating their crops or converting their land for other industrial uses. Figure 6 plots historical cane prices over the period 1988-89 to 2011-12 relative to the calculated RRM critical prices.

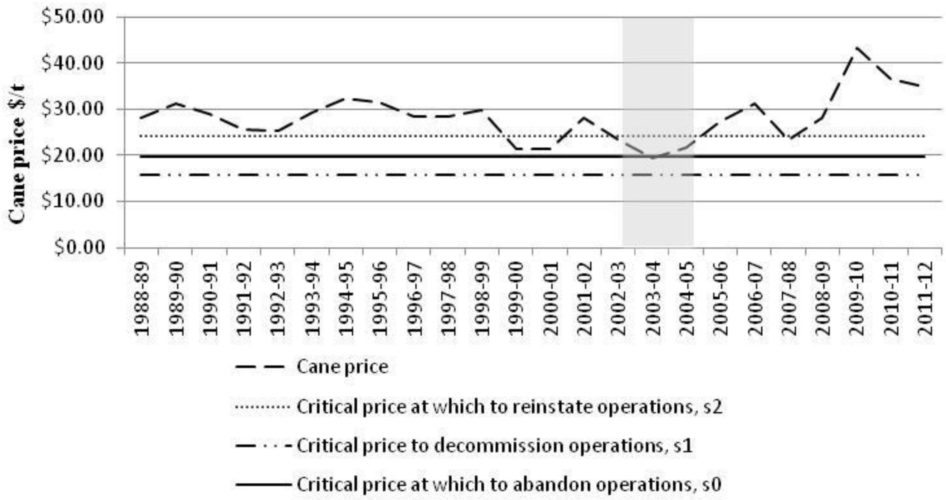


Figure 6. Historical cane prices relative to the RRM critical prices, 1988-89 to 2011-12

Figure 6 shows that there was no instance during 1988-89 to 2011-12 in which the cane price fell below the critical price, s_1, at which it is optimal to decommission sugarcane production on the farm. However, it is interesting to note that the cane price corresponding with the period 2003-04 was below the RRM critical price, s_0, at which it is optimal to abandon cane production on a previously decommissioned cane farm. Accordingly, had the price fallen to the critical price, s_1, the RRM indicates it would have been not only optimal to cease producing cane on the farm, but also worthwhile to abandon sugarcane production altogether.

In the case of this particular farming enterprise, the RRM evaluation indicates that it was optimal for the farmer to continue sugarcane production during 2003-04 given the likelihood that cane prices may be higher in the future. Incidentally, in 2004 the sugar industry was the beneficiary of a $444 million rescue package to assist eligible growers in the region to exit the industry, which included $350 million of new assistance money and $94 million of funds that remained from a package offered a couple of years earlier (see Hart, 2008). Despite a recovery in sugar prices occurring in the following years, it is estimated that, by 2008, 12 per cent of cane paddocks in the neighbouring sugar district of Tully were converted to managed-investment forestry schemes (Hart, 2008).

In instances where market prices are relatively low, the tax code may partially explain continued farm production despite the persistence of farm losses. Losses from farming are used to reduce taxes on other income, which may be the case for individuals operating small residential farms who report their primary occupation to be something other than farming. Similarly, large diversified commercial farms that are not stand-alone cane businesses may offset losses against other parts of the firm (see Moel & Tufano, 2002). In other words, for large, well-diversified firms, operating policy decisions may be made at the firm level rather than at the operational level.

It is also important to acknowledge that other subjective, non-financial considerations may further contribute to hysteresis inertia affecting operational decision making. These include such issues as the rural lifestyle, matters relating to farm business succession as well as the individual farm manager's attitude to risk more generally. Farmers may hold optimistic expectations regarding their future farming conditions and therefore continue operations despite an objective financial analysis indicating that it would be appropriate to do otherwise.

6. Conclusion

This case study presented a Real Options application using the Renewable Resource Model (RRM) to evaluate a farming enterprise consisting of 99.25 hectares of land under sugarcane in the lower Herbert district of north Queensland, Australia. It demonstrated how the RRM may be used to calculate the value of the farming enterprise using real-world data as well as the critical prices at which it is optimal for the farm operator to exercise various managerial options in order to maximise the value of their investment. In practical terms, the RRM is useful to assist farmers to make optimal decisions regarding whether or not to plant their field crops for the current season and at which price it is worth considering alternative uses for their crop land, such as rotating their crops or converting their land for other industrial uses. The implications for these types of managerial decisions on valuing agricultural assets are, by and large, exceedingly difficult to incorporate into financial valuations using conventional DCF methods.

Results of the case study indicate that the value of the cane enterprise in 2011-12 sugar prices was $1,380,000, which amounts to $13,904 per hectare ($5,629 per acre). While the average value of the enterprise over the period 1998-99 to 2011-12 was $762,500, which amounts to $7,683 per hectare ($3,110 per acre). The critical price at which to decommission cane production on the farm was calculated to be $15.75 per tonne of cane (IPS sugar price ~$188) and the price at which to recommence operations on a previously decommissioned farm $24.14 per tonne of cane (IPS sugar price ~$286). An interesting finding from the case study is that the RRM critical cane price at which to abandon a previously decommissioned cane farm turned out to predict remarkably well a period of low sugar prices where sugarcane growers within the region actually exercised their option to exit the sugarcane industry.

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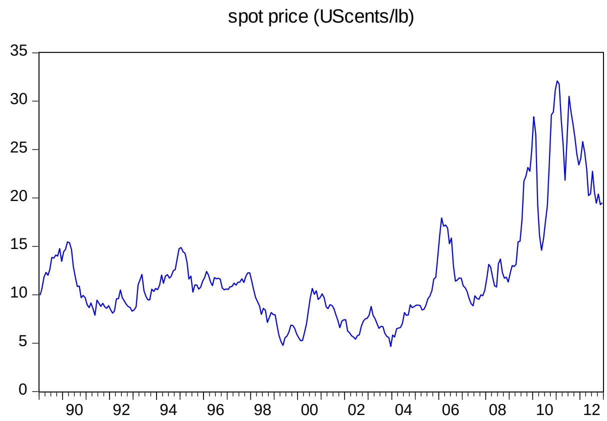
Appendix 1. Regressions



Null Hypothesis: SPOT_PRICE__USCENTS_LB_ has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.452153	0.1285
Test critical values:	1% level	-3.453072	
	5% level	-2.871438	
	10% level	-2.572116	

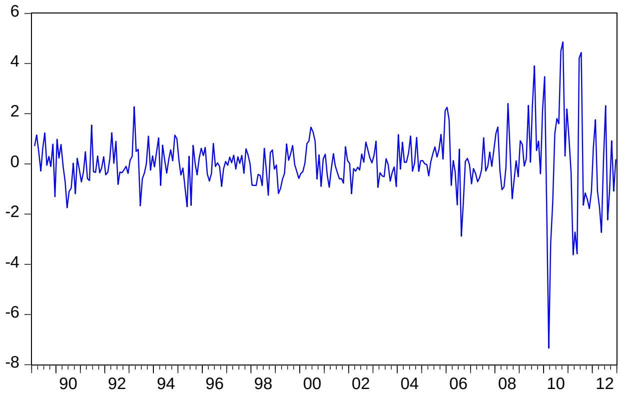
*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SPOT_PRICE__USCENTS_LB_)
Method: Least Squares
Date: 08/06/14 Time: 09:09
Sample (adjusted): 1989M03 2012M12
Included observations: 286 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SPOT_PRICE__USCENTS_LB_(-1)	-0.029001	0.011827	-2.452153	0.0148
D(SPOT_PRICE__USCENTS_LB_(-1))	0.365163	0.055489	6.580803	0
C	0.366979	0.156442	2.345788	0.0197

R-squared	0.140145	Mean dependent var	0.03087
Adjusted R-squared	0.134068	S.D. dependent var	1.203728
S.E. of regression	1.120135	Akaike info criterion	3.07521
Sum squared resid	355.0808	Schwarz criterion	3.113559
Log likelihood	-436.755	Hannan-Quinn criter.	3.090581
F-statistic	23.06258	Durbin-Watson stat	1.912277
Prob(F-statistic)	0		

Differenced spot price (UScents/lb)



Null Hypothesis: D(SPOT_PRICE__USCENTS_LB_) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-11.07025	0.0000
Test critical values:	1% level	-3.453153	
	5% level	-2.871474	
	10% level	-2.572135	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SPOT_PRICE__USCENTS_LB_,2)
Method: Least Squares
Date: 08/06/14 Time: 09:11
Sample (adjusted): 1989M04 2012M12
Included observations: 285 after adjustments

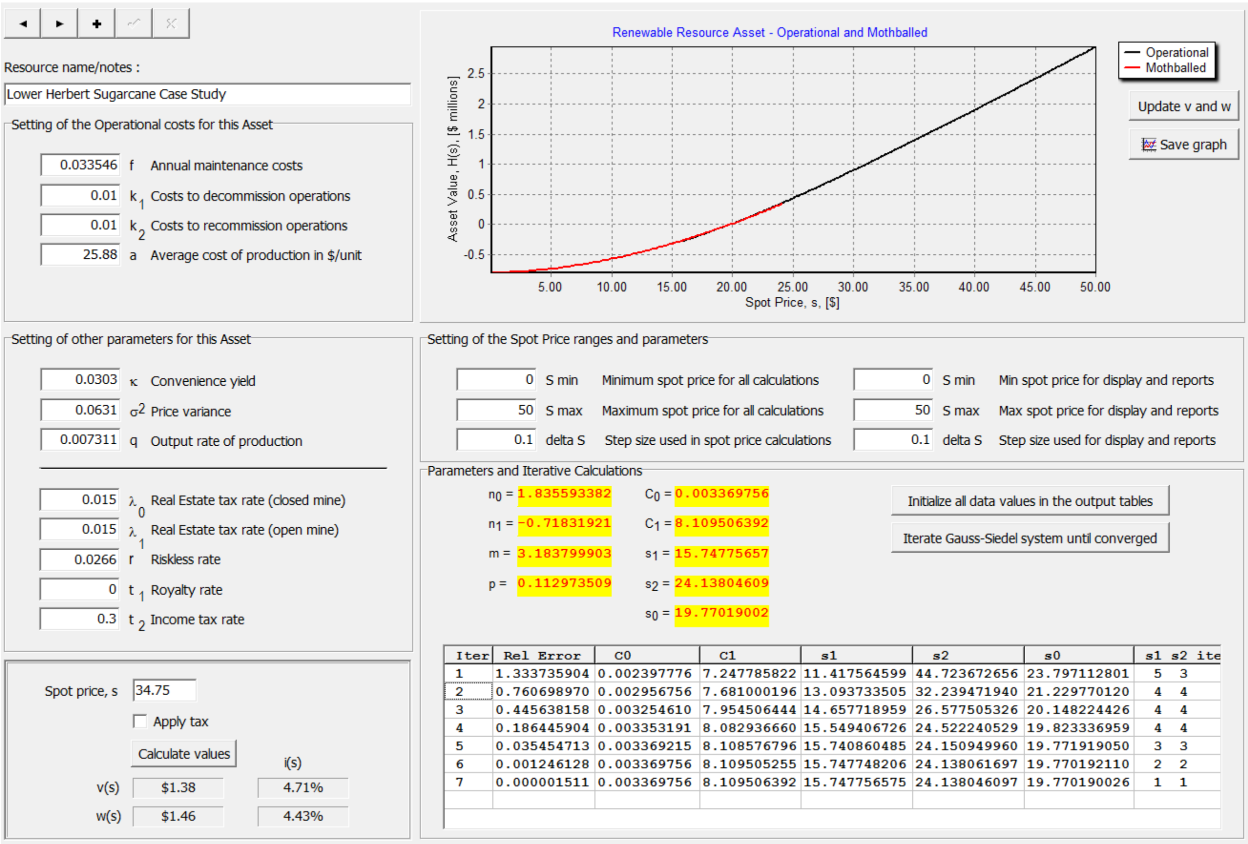
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(SPOT_PRICE__USCENTS_LB_(-1))	-0.743981	0.067205	-11.07025	0.0000
D(SPOT_PRICE__USCENTS_LB_(-1),	0.140646	0.058974	2.384856	0.0177
C	0.020068	0.066471	0.301901	0.763

R-squared	0.340314	Mean dependent var	-0.00337
Adjusted R-squared	0.335635	S.D. dependent var	1.375928
S.E. of regression	1.121499	Akaike info criterion	3.077681
Sum squared resid	354.6885	Schwarz criterion	3.116128
Log likelihood	-435.5695	Hannan-Quinn criter.	3.093093
F-statistic	72.73802	Durbin-Watson stat	2.008688
Prob(F-statistic)	0		

Appendix 2. Renewable Resource Model solution and implementation

The screen design layout of the RRM shown below consists of a separation of the input and output parameters. Once the data parameters have been input and initialised, the algorithm calculates the enterprise value at any spot price (shown at the bottom on the left hand side in $million) in addition to the critical spot prices that outline the optimal management operational policies to maximise the value of the asset (i.e. s_1, s_2 and s_0). The two separate output functions *v(s)* (operational - displayed in black) and *w(s)* (mothballed - displayed in red) that are displayed graphically at the top right of the implementation screen show the value of the sugarcane farming enterprise (in millions of dollars) on the vertical axis with respect to any cane price (in dollars per tonne) on the horizontal axis. In keeping with the specifications of the model (i.e. the farm is assumed to be operating under the optimal management policy that maximises the value of the enterprise) only the portion of the *v(s)* function above the critical price s_1, and the portion of the function *w(s)* below the critical price s_2 are shown.

Output screen for the RRM implementation



Running the parameters for the case study through the numerical implementation process, the RRM calculates the value of the sugarcane farming enterprise under each operating state as follows.
For the operating enterprise:

$$v(s) = c_1 s^{n_1} + \frac{q(1-t_1)(1-t_2)}{(\kappa+\lambda_1)} s - \frac{qa(1-t_2)}{(r+\lambda_1)}$$

Thus,

$$v(s) = 8.109506392 s^{-0.71831921} + \frac{q(1-t_1)(1-t_2)}{(\kappa+\lambda_1)} s - \frac{qa(1-t_2)}{(r+\lambda_1)}$$

For the temporarily decommissioned enterprise:

$$w(s) = c_0 s^{n_0} - \frac{f}{r+\lambda_0}$$

thus,

$$w(s) = 0.003369756 s^{1.835593382} + \frac{f}{(\kappa+\lambda_0)}$$