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How does real option value compare with Faustmann value in the context of the New Zealand Emissions Trading Scheme?

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ABSTRACT

Stochastic Dynamic Programming is used to determine the expected bare land value under the New Zealand ETS (Emissions Trading Scheme) with both log prices and carbon prices following a random walk. This value is substantially higher than the Faustmann NPV. This is in contrast to the situation without carbon where the difference is small and reduces as log price increases. When carbon is included, the difference in value is also large for existing stands and increases with stand age until at least the minimum harvest age is reached. Additional value comes from the flexibility of when to harvest and hence when carbon units have to be surrendered.

The real options approach also provides additional insight on the probability of a stand being harvested. Harvesting does not occur at low log prices and only occurs at higher log prices when carbon prices are relatively low.

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1. Introduction

Manley and Niquidet (2010) used three different option value approaches to estimate the value of a typical New Zealand plantation stand under the assumption that log prices follow a random walk. The estimated crop values were similar to Faustmann values estimated using constant log prices, except when log prices were low and close to the harvesting cost. Consequently they concluded that "at the present time, option valuation approaches have limited relevance for the practice of forest valuation in New Zealand."

However Manley and Niquidet (2010) only evaluated traditional forestry; i.e., forestry in which only revenues from log sales are included. They did not consider cashflows associated with carbon trading.

New Zealand was the first country to introduce an Emissions Trading Scheme (ETS) "that allows landowners to generate and trade reforestation and avoided deforestation credits that are compliant with Kyoto Protocol Article 3.3" (Hamilton et al., 2010). In 2008 the New Zealand Government enacted an Emissions Trading Scheme that is "designed to eventually cover all significant greenhouse gases (covered by the Kyoto Protocol) and involve all sectors in New Zealand. The primary unit of trade will be the New Zealand Unit (NZU). One NZU represents one tonne of carbon dioxide (CO_2) either released to the atmosphere (emissions) or removed from the atmosphere (removals)" (MAF, 2008).

Unlike the existing European Union ETS, the New Zealand ETS allows CO_2 credits to be obtained from forest sinks. Owners of Kyoto-compliant plantations (afforestation since 1 January 1990) are able to opt into the ETS and receive units for carbon sequestered. Conversely, they are required to surrender units when carbon stocks decrease. Pools included in the calculation of carbon stocks are above-ground live biomass, below-ground live biomass, coarse woody debris and fine litter. Soil carbon is not included because changes in soil carbon are generally small and difficult to measure at reasonable cost (MAF, 2008). Carbon stocks are determined, depending on whether the area is under or over 100 ha, either by (i) a look-up table approach or (ii) a field measurement approach. Participants are able to claim units for the annual change in carbon stocks.

The ETS adopts the current Kyoto Protocol rule that harvested carbon (i.e., logs extracted from the forest) is emitted at the time of harvest; i.e., the ETS excludes harvested wood products. Obligations under the ETS apply indefinitely until a participant exits from the ETS at which time they must meet any liabilities.

Carbon trading, through the provision of early cashflows, has the potential to change the economics of plantation forestry in New Zealand. Manley and Maclaren (2012) showed that the ETS could have a major impact on forest profitability, choice of species, silviculture and rotation length. For example the LEV (Land Expectation Value) for an example regime increased from \$1223/ha when carbon was excluded to \$3392/ha and \$6647/ha when carbon was included at \$15 and \$30/t CO_2. Optimum rotation age increased from 24 years to 26 and 30 years, respectively.

There have been concerns expressed by forest growers about the potential risk from future carbon price uncertainty. Carbon prices may be so high at the time of harvest, relative to log prices, that owners might not be able to afford to harvest. A consequence would be a reduction in the wood supply for the wood-using industry unless

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there was an increase in log prices; i.e., log prices and carbon prices could be correlated.

Analysis using the Faustmann approach (or an extension of it incorporating carbon) does not deal with stochastic prices. However the real options approach does. Although there have been a substantial number of papers using the real options approach to include stochastic log or wood prices in financial analyses, only a few recent papers have also considered carbon. Chladna (2007) used a real options model with stochastic wood and carbon prices to analyse optimal rotation age for a single rotation of spruce in Austria. She applied numerical analysis using partial differential equations. Wood price was assumed to follow the mean-reverting arithmetic Ornstein–Uhlenbeck process. Carbon price was assumed to follow geometric Brownian motion. Carbon price and wood price were assumed to be independent. In the absence of an actual carbon market, three alternative levels were evaluated for the proportion of total carbon for which units must be surrendered at the time of harvest. Optimal rotation age was found to depend on whether prices are constant or stochastic, whether carbon prices increase over time, the proportion of carbon units that need to be surrendered after harvest, and discount rate.

Guthrie and Kumareswaran (2009) also used partial differential equations in a real options model with stochastic log prices to study the effect of carbon credit allocation schemes on the timing of harvest and the replanting/deforestation decision for a representative radiata pine stand in New Zealand. They assumed that log prices follow a mean-reverting Ornstein–Uhlenbeck process and estimated parameters of the model using a discrete time AR(1) process. Carbon prices were held constant. They found that allocating carbon credits for carbon sequestration increased the optimum rotation age compared to the case of forest management without carbon credits.

Tee (2011) extended this work and used the binomial tree approach to develop a model incorporating both stochastic log and stochastic carbon prices in the calculation of the bare land forest investment opportunity for a New Zealand example under the ETS. He assumed that both log and carbon prices follow a mean-reverting Ornstein–Uhlenbeck process. As have Manley and Maclaren (2012), he found that the ETS will increase bare land value and lengthen rotation age. In addition, he found that, with variable log prices, bare land value was substantially higher with a flexible rotation age than with a fixed rotation age — $14,040/ha compared to $10,420/ha for the example analysed.

Petrasek and Perez-Garcia (2010) also used the real options approach to include carbon in a financial analysis of Douglas-fir in the US Pacific-Northwest. Expected bare land value was calculated using a Monte Carlo algorithm assuming that both wood and carbon prices follow logarithmic mean-reverting stochastic processes that are correlated.

The focus of this paper is on extending the previous work of Manley and Niquidet (2010) to include stochastic carbon prices as well as stochastic log prices. Whereas other studies have assumed both log and carbon prices (Petrasek and Perez-Garcia, 2010; Tee, 2011) or log prices alone (Chladna, 2007) are mean reverting, here the assumption is that both log and carbon prices follow a random walk. This study considers bare land value, as did Petrasek and Perez-Garcia (2010) and Tee (2011). However it also considers the situations of existing stands at a range of ages.

The initial question here is, in the context of the New Zealand ETS, how does real option value compare with Faustmann value? However the emphasis is also on using the real options approach to understand the impact of the ETS on the probability of a stand being harvested.

2. Approach

2.1. Price models

2.1.1. Log price model

Niquidet and Manley (2007) analysed historical log prices in New Zealand and found that virtually all log prices followed a non-stationary process. This initial study included three data sources including quarterly MAF log prices from 1994 to 2005. For this paper updated data (from September 1994 to March 2011) was tested using the same procedures:

- DF-GLS (Dickey Fuller) test both with and without a deterministic trend (null hypothesis non-stationary series),
- KPSS (Kwiatkowski, Phillips, Schmidt, and Shin) test (null hypothesis stationary series).

For all 10 log grades tested, the DF-GLS tests did not reject the null hypothesis of the series being non-stationary and the KPSS test rejected the null hypothesis of the series being stationary.

The empirical data indicates that New Zealand log prices follow a random walk rather than a mean-reverting process. Consequently analysis is done with a log price model of a non-stationary random walk with geometric Brownian motion (GBM). The discrete-time version of this is that the price at time t (P_t) has a lognormal distribution (i.e., P_t is lognormal with $\ln(P_t)$ normally distributed). The model implies that, in the case of annual prices:

$$\ln P_{t+1} = \ln P_t + \left(\mu - \sigma^2/2\right) + \varepsilon \tag{1}$$

where

μ	is expected annual change in log price (expressed as a proportion)
σ	is the standard deviation, i.e., the volatility (expressed on an annual basis)
ε	is a normal random variable with mean 0 and variance $=\sigma^2$.

2.1.2. Carbon price model

Determining an appropriate price model for carbon is problematic given the limited duration of the market. AgriFax[1] has been publishing a monthly price for NZUs since January 2010. The price of Certified Emission Reduction (CER) units on European Carbon Exchange has provided a benchmark price for NZUs that have been converted to AAUs (Assigned Amount Units) and sold to Norwegian and Danish government agencies. CERs can also be used by New Zealand emitters to meet their obligations under the New Zealand ETS. Time series for the price of CER daily futures exist from 13 March 2009 while prices for monthly futures with a settlement date of (for example) December 2012 start at 14 March 2008. The former is shown in Fig. 1.

Tests of stationarity were carried out on both CER series (for data through to 31 March 2011) in Euro and also after conversion to New Zealand dollars. For all four series the DF-GLS tests did not reject the null hypothesis of the series being non-stationary and the KPSS test rejected the null hypothesis of the series being stationary.

Consequently the carbon price model adopted is the same as that for log prices; i.e., a non-stationary random walk with geometric Brownian motion:

$$\ln C_{t+1} = \ln C_t + \left(\mu - \sigma^2/2\right) + \varepsilon \tag{2}$$

where C_t is the carbon price at time t.

2.2. Species, site and silvicultural regime

The example used is a radiata pine stand grown on an average New Zealand forest site (site index[2] 30 m, 300 Index[3] 25 m^3/ha/year) under

[1] www.nzxagri.com/agrifax.

[2] Mean top height of 100 largest stems/ha at age 20 years.

[3] 300 Index is an index of volume productivity. It is the stem volume mean annual increment at age 30 years for a defined silvicultural regime of 300 stems/ha (Kimberley et al., 2005).

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