Valuing the impact of climate change policies on forestry

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Abstract

Conventional forest valuation approaches do not account for discretions foresters have in making key irreversible decisions, such as when and if to harvest in the light of uncertain future decision variables. Furthermore, where they are sufficiently sophisticated as to make explicit forecasts of future valuation parameters such as log prices at harvest date, as is the case for discounted cash flow (DCF) analysis, they do so with unavoidable imprecision. These shortcomings – as well of those of even less sophisticated methodologies such as cost- or transaction-based valuations – become telling when attempting to assess the impacts of long-term climate change policies on forest values. This paper presents an alternative approach using real options analysis that captures enough complexity to meaningfully model the impacts of climate change policies on forest value, while remaining relatively straightforward to implement using Monte Carlo simulation. It shows that foresters' discretions as to when and if to harvest, or to convert to non-forest land uses, give rise to real options whose value is captured by real options analysis but ignored by conventional forest valuation methodologies. It furthermore shows how forest values differ, and conversion rates vary over time, depending on which climate change policies or policy uncertainties are assumed. In short, Kyoto forests (those first planted after 1989) are more valuable when carbon credits and harvest liabilities under the Kyoto Protocol are devolved by the Crown to their owners. Non-Kyoto forests (those planted before 1990) are more valuable when deforestation liabilities are not devolved to their owners. Current New Zealand policy, under which deforestation liabilities are retained by the Crown only within limits, encourages the early conversion of Non-Kyoto forests into non-forest uses.

Introduction

Forest valuation requires assumptions about the highly uncertain future values of numerous variables. Key among these have traditionally been log yields, tending and harvesting costs, and log prices. Increasingly it is recognised that regulatory uncertainties also impinge on expected forest values, for example where they limit harvesting technologies and hence costs, or where they restrict changes in land use following harvest, for example where future departures from plantation forestry are expected to have adverse impacts on water quality or erosion.

With New Zealand's ratification of the Kyoto Protocol (the Protocol), additional regulatory uncertainties now arise. These include questions as to how the Crown, as party to the Protocol, will implement domestic policies to influence the behaviour of foresters so as to enable it to meet its Kyoto commitments. Such policies include the extent to which owners of forests first planted after 1989 (so-called "Kyoto forests") will be awarded tradable carbon credits in recognition of the carbon dioxide sequestered in their trees, and also any associated liabilities for carbon dioxide deemed released under the Protocol when those forests are harvested. Under current New Zealand policy such credits and liabilities are to be retained by the Crown.

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Other relevant policies include the extent to which, or conditions under which, owners of forests first planted before 1990 (so-called "Non-Kyoto forests") will face liabilities based on the carbon deemed released under the Protocol should they decide to change the land beneath their forests into non-forestry uses. Current New Zealand policy is that the Crown will retain any such liabilities in respect of 2008 through 2012 inclusive – the so-called first commitment period (or CP1) – provided total deforestation in CP1 does not exceed a pre-specified level (or Cap). It is currently uncertain what the Crown will do in the event that the Cap is breached, with options ranging from lifting the Cap through to managing or allocating deforestation rights among Non-Kyoto forest owners.

Many other uncertainties arise under both the Kyoto Protocol and New Zealand's climate change policies. Foremost is the lack of certainty as to what rules will apply after 2012 (i.e. beyond CP1), to New Zealand let alone to foresters under domestic policy. Moreover, it is currently unclear whether liabilities from the deforestation of Non-Kyoto forests will lie with forest owners or landowners (which will matter where trees are owned separately from land). For long-lived investments such as forestry such policy uncertainties materially affect foresters' incentives to harvest, deforest and/or (re)plant. Additionally, even if New Zealand foresters faced certain climate change rules, they now also face uncertainty as to a new, potentially key, decision variable – the price at which they could sell any carbon credits, or at which they must purchase emission rights to cover any harvesting or deforestation liabilities. This "world price of carbon" is not only currently hard to measure, but like log prices it should be expected to be particularly volatile over the life of a forestry investment, thus fundamentally affecting forest economics.

Aside from uncertainty as to climate change policies and the world price of carbon, forest valuation is additionally complicated by the fact that it requires assumptions as to how the forest will be managed over an extended number of years. How the forest is managed – critically, if, when and under what conditions it should be harvested – will naturally affect the value forest owners can expect to derive from their investment. These management decisions now must not only account for log yields, prices and costs, but also possible carbon credit revenues and or harvest or deforestation costs.

This paper argues that conventional forest valuation practices are inadequate to properly account for the impacts of climate change policy on forest value. It describes the application of a valuation method known to financial economics since the 1960s – so-called "real options analysis" – to the problem of valuing forests under the Kyoto Protocol.[1] First it summarises the particular valuation problem. Then it highlights why conventional forest valuation methods such as discounted cash flow (DCF) analysis and other, historically-oriented methods (cost- and transaction-based methods) cannot capture the valuation impacts of climate change policy. This is followed by a description of the real options approach offered as an alternative to conventional valuation techniques, and a discussion of that approach's predictions. The final section summarises and concludes.

The Valuation Problem

Kyoto Forests

It is assumed that future log yields and forestry costs are known with certainty. The remaining uncertainties relate to future log prices and the world price of carbon. To make the analysis more realistic, log and carbon dioxide prices are assumed correlated. Under DCF analysis it is common to assume a fixed harvest date, whereas in reality foresters have considerable discretion as to when (and if) to harvest, depending on circumstances at the time of harvest (such as the level of log prices). Thus the valuation problem should allow for forestry costs (i.e. planting, tending, etc) for either a fixed (DCF) or variable (more realistically) number of years.

For Kyoto forests it is also necessary to specify if and when any carbon credits accrue to the forester. Thus it is not only necessary to estimate the world price of carbon at harvest date, but also at the dates at which any such credits accrue. The world price of carbon is relevant at the harvest date if and to the extent that the forester is liable for any harvest or deforestation liability. Moreover, assumptions are also required as to what the forester will do with any credits accrued – simply stockpile them to use to offset any future harvest liability, or sell some or all credits as they accrue (and hence have to purchase emission rights to cover any Kyoto liabilities on harvest). Finally, assumptions are required as to what Kyoto Protocol rules and domestic climate change policies will apply beyond CP1.

Non-Kyoto Forests

The difference in this case (compared to Kyoto forests) is that no carbon credits are derived by Non-Kyoto forest owners unless and until the Kyoto Protocol rules or domestic policies are changed to provide for this. On the other hand, there is a contingent risk that the Crown will devolve deforestation liabilities on forest (or land) owners, in which case the economics of changing existing forest land into alternative uses (such as dairying) become more uncertain. Under Kyoto rules, however, no such liabilities arise prior to 2008, creating a window for liability-free conversion. This possibility is made more attractive under current New Zealand policy by the lack of emissions liability for agriculture, since conversion to dairying (for example) pre-2008 not only avoids any possible deforestation liability, but it also enjoys freedom from ongoing emissions liabilities (subject to any future policy change on agricultural emissions). Thus Non-Kyoto forest values must now also take into account the risk and likely cost of deforestation liabilities, the possibility of converting forest land into alterative uses, and the relative economics of forestry and such uses.

Shortcomings of Conventional Valuation Approaches

Discounted Cash Flow (DCF) Analysis

DCF analysis has the merit of being a forward-looking valuation approach, seeking to calculate the present value of expected future forestry costs and returns, discounted at some appropriate risk-adjusted discount rate.[2] In principle, therefore, it would take into account how climate change policy affects future forest returns. In turn optimal harvest dates can be derived in the light of any expected carbon credit accruals, net of any expected harvest or deforestation liabilities. Where future climate change policies are uncertain, probabilities can be attached to and expected cash flows derived for each relevant policy scenario. Where Non-Kyoto forests are being valued, and the likelihood of conversion from forestry into an alternative land use becomes relevant for determining any deforestation liabilities, in principle these also could be modelled.

But the DCF approach has key limitations. Aside from climate change policy issues, any DCF analysis requires estimation of log prices often decades in the future, which is inherently problematic given log price volatility. With climate change issues, correlated carbon dioxide prices must also be forecast, increasing the prediction problem by orders of magnitude. For Non-Kyoto forests this is even more so, since the economics of deforestation (e.g. dairy conversion) must also be modelled, for example requiring predictions as to future dairy milk solids prices. The

[1] *See, for example, Dixit and Pindyck (1994) for a discussion of real options valuation methods.*

[2] *See, for example, the summary of such techniques as provided in Manly (1995).*

vulnerability of forest valuations to misestimates of future prices becomes all the more telling once climate change impacts on value are considered.

More fundamentally, DCF analysis suffers from its assumption that harvest will occur at a fixed future harvest date, at current estimates of future log prices, irrespective of what future harvest conditions turn out to be. It ignores foresters' discretions to defer harvest should conditions be unfavourable at harvest date, in the hope that later harvest will be more profitable. Once the accrual of carbon credits and/or harvest or deforestation liabilities are considered, such a naïve harvest date assumption can critically distort estimated forest value. In reality, taking climate change policies into account a forester may defer harvest based also on whether carbon dioxide prices are also unfavourable. And for Non-Kyoto foresters, any future decision to harvest and convert into (e.g.) dairying will depend not just on the prevailing milk solids price, but also on carbon dioxide prices.

In short, where forestry involves irreversible or partly irreversible decisions such as harvest or deforestation, and the key variables affecting those decisions are uncertain, DCF analysis ignores valuable options the forester possesses to accelerate or defer those decisions in the light of future conditions. It thus should be expected to understate forest value, assuming it has even been applied with sufficient sophistication to properly account for the additional decisions foresters will need to make under climate change policy.

Historically-Oriented Valuation Methods

The picture is even less rosy for historically-oriented forest valuation approaches. Cost-based methods simply ignore future carbon credit revenues, or imposts for harvest or deforestation. Additionally they do not naturally accommodate the costs of possible future deforestation/ conversion, and so lack the capacity to reflect potential deforestation liabilities. Transaction-based methods, considering traded forest values where recent such figures are even available for comparable forests, are potentially less constrained. At least traded forest values should impound a "market-based" assessment of what future climate change policies amount to in present value terms. The difficulty, aside from obtaining such figures, is that they beg the question as to how the assessment has been made. If DCF analysis was used then the assessment should be regarded as wanting. Where less "science" is involved this is only more so. Furthermore, even if traded forest values accurately reflect the impact of climate change policies and policy uncertainties at the time of the transaction, this offers no guidance on what forest value should be if those policies, policy uncertainties, or other relevant pricing variables changed since the transaction date. This means neither cost- nor transaction-based approaches are helpful in assessing the value impact of alternative policy options. Given the current flux in New Zealand's climate change policies these methods are therefore not useful for measuring the impact of such policies on forest value.

Alternative Approach using Real Options Analysis

DCF and Real Options Approaches Contrasted

Unlike DCF analysis and cost-or transaction-based valuation approaches, real options analysis explicitly models foresters' discretions over future forest management. Such discretions include when to harvest, under what conditions should harvest be deferred, and/or if harvest should be abandoned altogether. For Non-Kyoto forests they also include when and if to harvest and convert forest land into some alternative land use. In turn these discretions are assumed contingent on the future values of key decision variables such as log, carbon dioxide and/or (e.g.) milk solids prices. In this light DCF analysis can be seen to be a highly constrained special case of real options analysis, namely one in which it is assumed the forester has no choice but to harvest at the pre-specified harvest date, and where there is certainty rather than uncertainty as to future log prices and other relevant decision variables.

Another critical departure between real options and DCF analysis relates to how these future decision variables are modelled. Instead of making some point estimate of what value each decision variable will take at the relevant decision dates, explicit account is taken of the dynamics and uncertainties of those variables. Commonly this achieved by assuming each variable follows some pre-specified "stochastic model" characterised by key parameters such as current values, correlations between the variable and its past values, and volatility in those variables. Additionally, correlations across different decision variables can also be modelled. Hence, instead of making heroic projections as to what long-distance future values those variables might take, it is assumed that those variables will follow one of many available dynamic models for how they evolve over time.

Applying such dynamic models and modelling such discretions can take one of many forms. For simpler valuation problems it is sometimes possible to derive explicit valuation formulas that can then be calculated based on currently available information to estimate forest value.[3] For more realistic problems various numerical solution techniques are required, with one of the simpler techniques involving Monte Carlo simulation.[4] In practice the complexity of the problem being valued is constrained by the lack of or difficulties in applying a suitable solution technique, particularly when there are multiple decision variables. Consequently often only approximate real options valuations, or lower and/or upper valuation bounds, can be derived.

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[3] *The most famous example of such a formula is the Black-Scholes model for pricing financial options. See, for example, Hull (1997).*

[4] *See, for example, Schwartz and Trigeorgis (2001). The author has applied this approach for forest valuation using a spreadsheet and the commonly-available commercial simulation add-in package @RISK.*

Real Options Model for Forest Valuation

In the case of valuing climate change policy impacts on Kyoto and Non-Kyoto forest values the author has developed a real option approach that produces a lower bound on forest value, which lower bound is higher than DCF-based valuations (where DCF analysis can even be meaningfully applied). Log, carbon dioxide and, for Non-Kyoto forests, milk solids prices are modelled using a mean-reverting pricing process commonly used to model commodity prices.[5] Monte Carlo simulation is used to simulate future paths for such prices and to derive forest values based on assumed forester discretions and climate change policies. The real options approach is warranted given uncertainty in key decision variables (i.e. prices), and the irreversibility of the harvest decision. It is assumed that whatever climate change policies apply in CP1 will roll over to subsequent commitment periods.

In respect of Kyoto forests, foresters are assumed able to feasibly harvest within a fixed harvest window, in each year either harvesting or deferring harvest (and in the final possible harvest year, possibly abandoning harvest should it prove to be uneconomic). A harvest threshold is modelled in each year that must be reached before the valuable option to defer harvest is extinguished by choosing to harvest. This threshold is calibrated empirically so as to maximise forest value, and declines towards zero as the latest feasible harvest date is approached. Where carbon credits and harvest liabilities are assumed devolved to Kyoto foresters, it is assumed that credits are sold as they accrue at the prevailing carbon dioxide price, and emission rights are subsequently purchased to cover harvest liabilities if and when harvest occurs. Thus the forester will harvest the forest in any year only if the returns from doing so exceed the costs of harvesting the trees and purchasing any required emission rights, and do so by a time-declining margin reflecting the valuable option to defer harvest.

For Non-Kyoto forests, the relevant discretions in any year are assumed to be to harvest and replant, or to harvest and convert into dairying. As for Kyoto forests a declining threshold is assumed for the harvest and replanting decision within the feasible harvest window. Conversely, the option to harvest and convert into dairying is not assumed to be time-constrained, although it is assumed to be lower pre-2008 relative to post-2007 to reflect the possibility of deforestation liabilities post-2007 but the absence of such liabilities beforehand. As for the option to defer harvest and replanting, a threshold must be reached before the option to harvest and convert is exercised, and this threshold is determined empirically (along with the harvest and replanting threshold) to maximise forest value. Thus the forester will harvest and replant, harvest and convert, or defer either decision, depending on whether the respective returns from doing so exceed the relevant combined decision boundaries. Should neither decision be taken by the latest possible harvest date, the forest is assumed abandoned. To model uncertainty in whether or not deforestation liabilities will be devolved to forest owners in CP1 under current New Zealand policy, a non-zero probability of devolution in any given year is assumed. Should devolution occur in any year, it is assumed that deforestation liabilities remain so devolved subsequently.

Real Options Results

The real options approach described above produces results consistent with both expectations, and in respect of Non-Kyoto forests, anecdotal evidence on current forester behaviour. Kyoto forest values are higher using real options analysis than with DCF analysis. Average harvest age is also higher than typically assumed in DCF analyses. Furthermore, forest values are higher with the devolution by the Crown of both carbon credits and harvest liabilities to foresters, relative to status quo policy under which the Crown retains them both. As the carbon dioxide price rises, this value advantage initially rises, stabilises, and then continues to rise again. This illustrates that rising carbon dioxide prices add to the value of plantation forestry with carbon credits and harvest liabilities devolved, but that beyond a certain carbon dioxide price, forest values become tied more to carbon sequestration than they are to wood production. The option to abandon harvest is sometimes valuable in the case of devolved credits and liabilities, as the cost of acquiring necessary emission rights is in some cases prohibitive.

For Non-Kyoto forests the option to harvest and convert into dairying is found to be frequently more valuable than the option to harvest and replant. Under status quo policy – with the possible devolution of deforestation liabilities to Non-Kyoto foresters should the deforestation cap be breached in CP1 – the overall rate of harvest and conversion is lowest relative to either the certain devolution or certain non-devolution of such liabilities. However, under status quo policy the rate of conversion pre-CP1 increases dramatically relative to a policy of certain non-devolution of deforestation liabilities. Indeed, the total conversion rate both pre- and intra-CP1 is higher under status quo policy than under a policy of certain non-devolution. This indicates that current Kyoto policy is in fact accelerating the rate of conversion pre- and intra-CP1, relative to a policy in which Non-Kyoto foresters face no deforestation liability. As expected, forest values are highest where full conversion options are available, which arises under a policy of certain non-devolution of deforestation liabilities. Current climate change policy produces lower relative forest values, with a policy involving the certain devolution of such liabilities producing the lowest relative values.

Summary and Conclusions

Limitations in conventional forest valuation approaches become telling when attempting to assess the impact of alternative climate change policies on forest value. The real options approach is more complicated to implement than conventional valuation approaches, but enables explicit modelling of forester decisions as they affect the impact

[5] *The so-called Ornstein-Uhlenbeck process. See, for example, Dixit and Pindyck (1994).*

of climate change policies on forest value. It also assumes methods for determining the future values of key decision variables that do not require the use of heroic projections. The approach suggested in this paper has the advantage of modelling forester discretions that in practice are widely acknowledged, if not valued using conventional methodologies. Like many other real options valuation models, it produces an approximate – in this case lower bound – forest value, rather than an exact value estimate. Reduced valuation accuracy (relative to a theoretical ideal) is the price of needing to model a minimum level of complexity to meaningfully measure the impact of climate change policy on forest value. Relative to DCF analysis, however, or historically-oriented valuation approaches, the real options approach is considerably more accurate, since it uses both more robust methods to generate future values of key decision variables, and more realistic assumptions as to how future forestry decisions will be made. Since foresters' discretions give rise to valuable real options, it is no surprise that the real options analysis produces forest values in excess of those produced using DCF analysis, since DCF analysis omits the value of such real options.

In the context of the current debate between foresters and government as to optimal climate change policy, the real options analysis also produces more reliable estimates of the impact on forest value of different policy options. Furthermore, unlike conventional forest valuation approaches, it can quantify the rate and timing of forester decisions – such as when and at what rate deforestation by Non-Kyoto foresters can be expected in CP1 – which further assists government to gauge the fiscal risk attaching to its Kyoto Protocol obligations under alternative policy settings. Given the potential significance of climate change policy for forest values, it is perhaps timely to take forest valuation practice in New Zealand to required new levels of sophistication.

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