Analysis of New Zealand forest transactions 2011–2013

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Abstract

Data from 27 New Zealand forest transactions were analysed and a model developed to predict crop value from the discounted stumpage revenue associated with the average stand in each forest that was sold in 2011–2013. Inputs to the model are average age (adjusted for species mix), total recoverable volume, harvest cost, distance to port and the proportion of pruned area. Parameters in the model are log price, pruned log price differential, unit transport cost and discount rate. Although the model explains 65% of the variation in crop value, it only predicts the value of 20 out of the 27 transactions to within $2,000/ha of the actual value.

Introduction

Respondents to the 2013 NZIF Discount Rate Survey were asked to provide information on the discount rates they used for forest valuation as well as the discount rates implied by recent transactions. Results were reported by Manley (2014). In addition, valuers were asked to provide information on recent transactions. This paper analyses these transactions. In particular, it attempts to develop an overall model to predict the value paid for each forest from underlying variables.

The approach taken parallels the study of Manley and Bell (1992), which analysed data from 12 transactions involving the cutting rights to state plantations. The model developed in that study predicted forest value as a function of the discounted net clearfell revenue less silvicultural and overhead costs. The model had parameters to represent transport cost and discount rate.

Method

Valuers were asked to provide information on transactions between mid-2011 and 2013:

- Average value ($/ha)
- Net stocked area (ha)
- Region
- Proportion of area in radiata pine
- Proportion of area pruned
- Average age\(^1\)
- Average volume at age 30 years\(^2\) (m\(^3\)/ha)
- Average harvesting cost ($/m\(^3\) for logging, loading, roading and overheads)
- Distance to port.\(^3\)

Most valuers provided the value of the tree crop. In some cases, the value included land value. Crop value was subsequently calculated by deducting land value from the forest value provided. Analysis was carried out using the R statistical package.

Results

Data was provided for a total of 27 transactions. These represent many, but not all, of the forests for which implied discount rates were reported in Manley (2014). Crop value ranged from $1,450/ha to $16,245/ha. The forests sold cover a range of maturity, proximity to port, harvest difficulty, productivity, species mix and silvicultural input (Table 1).

Table 1: Minimum, mean and maximum value for variables reported for the 27 transactions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop value ($/ha)</td>
<td>1,450</td>
<td>6,636</td>
<td>16,245</td>
</tr>
<tr>
<td>Average age</td>
<td>4</td>
<td>17</td>
<td>32</td>
</tr>
<tr>
<td>Distance to port (km)</td>
<td>25</td>
<td>92</td>
<td>190</td>
</tr>
<tr>
<td>Harvest cost ($/m(^3))</td>
<td>19</td>
<td>38</td>
<td>50</td>
</tr>
<tr>
<td>Volume at age 30 (m(^3)/ha)</td>
<td>380</td>
<td>618</td>
<td>814</td>
</tr>
<tr>
<td>Radiata pine proportion</td>
<td>0.76</td>
<td>0.96</td>
<td>1</td>
</tr>
<tr>
<td>Pruned area proportion</td>
<td>0</td>
<td>0.55</td>
<td>1</td>
</tr>
</tbody>
</table>

Adjustment to age

All blocks had at least 76% of the area in radiata pine. The remainder of the area was mostly Douglas-fir. To allow for longer rotation ages for this species, age was reduced by 15 years for the proportion of non-radiata pine area and an adjusted average age calculated. The

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\(^1\) Valuers were also asked for minimum and maximum age but this information was not consistently supplied.

\(^2\) Some valuers provided volume at different ages. This was converted to a volume at age 30 on the basis of mean annual increment.

\(^3\) Distance to port was asked for because it represents a more objective measure than distance to market.
assumption is that a non-radiata pine stand of a given age is equivalent in maturity (years to clearfelling) to a radiata pine stand that is 15 years younger.

**Correlation of value with predictive variables**

Average age is the only variable that is significantly correlated with value (Table 2). It explains 44% of the variation in value. The pruned area proportion explains 7% of the variation, while the other variables (on their own) explain less than 1% of the variation in value.

### Table 2: Correlation coefficient r and r² for the relationship between value and potential explanatory variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation coefficient (r)</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age (adjusted)</td>
<td>0.667</td>
<td>0.445</td>
</tr>
<tr>
<td>Distance to port (km)</td>
<td>0.033</td>
<td>0.001</td>
</tr>
<tr>
<td>Harvest cost ($/m³)</td>
<td>0.047</td>
<td>0.002</td>
</tr>
<tr>
<td>Volume at age 30 (m³/ha)</td>
<td>0.094</td>
<td>0.009</td>
</tr>
<tr>
<td>Radiata pine proportion</td>
<td>−0.021</td>
<td>0.000</td>
</tr>
<tr>
<td>Pruned area proportion</td>
<td>0.262</td>
<td>0.069</td>
</tr>
</tbody>
</table>

While the relationship between value and age is significant there is a lot of unexplained variation (Figure 1). For example, six of the forests have an average age between 14 and 16 years and their value varies between $4,646/ha and $11,700/ha.

**Model based on expectation value**

Manley and Bell (1992) developed a model based on the expectation value approach to forest valuation:

\[
\text{Value ($/ha)} = \text{discounted stumpage revenue} - \text{discounted annual costs} - \text{discounted silvicultural costs}
\]

A similar approach is attempted here. However given that there is only one forest that is aged under nine years, there was insufficient data to consider a silvicultural costs term. Stumpage revenue can be expanded:

\[
\text{Stumpage revenue} = (\beta_1 - \beta_2 \times \text{distance to port} - \text{harvest cost}) \times \text{volume}_{30}
\]

Where \(\beta_1\) = at-wharf price ($/m³)

\(\beta_2\) = unit transport cost ($/m³/km)

The discount factor for stumpage revenue:

\[
\text{discount factor} = 1/(1+\beta_3)^{30-\text{Age}}
\]

Where \(\beta_3\) = discount rate

\(\text{Age} = \text{adjusted average age}\)

Consequently a non-linear model was tested:

\[
\text{Value} = \left[ (\beta_1 - \beta_2 \times \text{distance to port} - \text{harvest cost}) \times \text{volume}_{30} \right] / (1+\beta_3)^{30-\text{Age}}
\]

(Model 1)

Where \(\beta_1\), \(\beta_2\) and \(\beta_3\) are parameters to represent at-wharf price, unit transport cost and discount rate.

Regression coefficients for price and discount rate are significant, but not for transport cost (Table 4). Model 1 has an RSE of 2662 and an R² value of 42%.
Model 1 was extended to take into account pruning. Additional revenue from pruned forests was estimated as \( \beta_4 \times \text{pruned} \times 0.25 \times \text{volume}_{30} \) where the parameter \( \beta_4 \) represents the price premium paid for pruned logs. It is assumed that 25% of the volume from any stand that has been pruned will be in pruned log grades. This volume is scaled by the percentage of the forest that has been pruned. This leads to Model 2:

\[
\text{Value} = \left( (\beta_1 + \beta_4 \times \text{pruned} \times 0.25 - \beta_2 \times \text{distance to port} - \text{harvest cost} \times \text{volume}_{30} ) / (1 + \beta_3) \right)^{30-\text{Age}}
\]

Model 2 (Table 5) has an RSE of 2154 and an \( R^2 \) value of 64%. All coefficients are significant.

Table 5: Regression coefficients for Model 2

<table>
<thead>
<tr>
<th>Regression coefficient</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>At-wharf price ($/m^3$)</td>
<td>( \beta_1 ) 68.15 &lt;0.001</td>
</tr>
<tr>
<td>Pruned log price premium ($/m^3$)</td>
<td>( \beta_4 ) 74.66 &lt;0.001</td>
</tr>
<tr>
<td>Transport cost ($/m^3$/km)</td>
<td>( \beta_2 ) 0.103 0.019</td>
</tr>
<tr>
<td>Discount rate</td>
<td>( \beta_3 ) 0.085 &lt;0.001</td>
</tr>
</tbody>
</table>

Model 3:

\[
\text{Value} = \left( (\beta_1 + \beta_4 \times \text{pruned} \times 0.25 + \beta_5 \times \text{other} - \beta_2 \times \text{distance to port} - \text{harvest cost} \times \text{volume}_{30} ) / (1 + \beta_3) \right)^{30-\text{Age}}
\]

Model 3 (Table 6) has a an RSE of 2202 and an \( R^2 \) value of 64%. It implies that the average price for other species (predominantly Douglas-fir) is $4.69 less than the average unpruned price for radiata pine. However this coefficient is not significant, so consequently Model 2 is the preferred model.

An attempt was also made to include annual overhead costs in the model using the approach of Manley and Bell (1992). However the model developed was not significant and not logical – an annual revenue of $310/ha/year was implied rather than an annual cost.

Model 2 performance

Model 2 predicts the value of 20 of the 27 transactions to within ±$2,000/ha (Figure 2). However there are three outliers for which the model underpredicts by more than $2,000/ha and four outliers for which the model overpredicts by more than $2,000/ha. For one of the forests that had value underestimated, existing infrastructure and access to diverse markets could be a factor. However no common patterns could be observed in the outlier groups.

![Figure 2: Residuals (calculated as actual value minus predicted value) plotted against adjusted average age](image-url)

The wide distribution of residuals in Figure 2 is not surprising given the range of implied discount rates reported in Manley (2014). Implied discount rates reported for New Zealand forests varied between 5.1% and 11.5%. Using a model such as Model 2 with an ‘average’ discount rate of 8.6% will result in crop value being poorly estimated in some cases.

Discussion

Model interpretation

Model 2 explains 64% of the variation in forest value using a model structure that is based on the
discounted stumpage revenue of the average stand in each forest. The model parameters can be compared with industry practice:

- The discount rate parameter of 8.6% is broadly comparable with the average implied discount rate of 8.9% (for pre-tax cashflows) reported in the 2013 survey (Manley, 2014).
- Average at-wharf prices for unpruned logs during 2011 to 2013 were $80–100/m³, certainly higher than the calculated price coefficient of $68/m³.\(^4\)
- Pruned log prices were $40–50/m³ higher than average unpruned log prices during 2011 to 2013, lower than the $75/m³ premium estimated.
- Unit transport costs are typically higher than $0.10/m³/km, for example, the AgriFax log price report for June 2013 implies a unit transport cost of $0.13/t/km.

Some of these differences will reflect the assumptions made, for example, the assumption that all logs are transported to the port will result in an over-estimation of transport distance for many forests. The lower unit cost estimated in the model may be compensating for this. Similarly the pruned log premium assumes a pruned log percentage of 25%. A higher percentage would result in a reduced coefficient. However in many cases the pruned log percentage would be lower than 25% and result in an even higher pruned log price differential in the model.

**Other species**

Although the price differential estimated for other species in Model 3 was not significant, use of an age adjustment means that the relative maturity of non-radiata pine species is captured in Model 2. When Model 2 was re-estimated using raw (i.e. unadjusted) average age, the RSE increased from 2154 to 2286 and \(R^2\) decreased from 64% to 59%. This confirms that adjusting age to reflect species mix is warranted. Figure 3 shows the effect on RSE of varying the age reduction for other species from 0–25 years. The underlying model is Model 2, with average age calculated using different age reductions for the proportion of non-radiata pine species.

- There was a single seller in the 1990 transactions.
- In 1990, the cost of using land was standardised as a Crown Forest Licence rental.
- Due to limited transaction evidence, reserve prices calculated by the Crown played a large role in the 1990 sale and purchase negotiations. These were calculated using a standard approach and calibrated using initial transactions. The 2011–2013 transactions involved many different buyers and sellers, all with a wide range of perceptions about forest value and motivations for sale or purchase.

**Acknowledgements**

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**References**


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\(^4\) Prices are derived from an analysis of AgriFax prices done as part of Management Case Study 2014 by final year BForSc students.