Economics of in-forest debarking of radiata pine in New Zealand and Australia

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Abstract

Restructuring has been recommended as an approach for improving forestry supply chain efficiency. In-forest debarking (IFD), as opposed to debarking at mills or ports, is an example of supply chain restructuring. No debarker head capable of pine IFD is currently available.

The aims of the research reported in this paper are quantifying the potential costs and benefits of IFD of *Pinus radiata*, and identifying the maximum capital costs that could be paid for modified mechanised harvester/processor heads to debark logs.

Economic models were developed that allowed quantification of the potential costs and benefits of IFD, as well as breakeven costs for a purpose-built pine debarker head. The models spanned from forest establishment through to delivery of logs to mills or shipside. The models were populated with data from a mix of trials carried out in New Zealand and Australia, forest industry sources and published figures.

The models indicated that, for both Australia and New Zealand, IFD might be an economically viable alternative to debarking further along the supply chain. Potential gains in net revenue of 3% to 9% were possible. Breakeven prices for a pine debarker head ranged from $245,000 to $800,000. Net revenue gains and breakeven prices were sensitive to some key factors. The effect of value losses associated with sapstain following IFD deserves further research.

Introduction

Bark accounts for 11.8% of radiata pine over-bark volume in natural stands in the United States (Miles & Smith, 2009). It accounts for 12% to 13% of over-bark volume and 7% to 8% of over-bark green weight for mature radiata pine boles in New Zealand prior to felling and log handling (Murphy & Cown, 2015). Radiata bark volume percentage decreases with increasing height up the stem, increasing tree size, and decreasing mean annual temperature.

Based on current harvest volumes, about 1.5 million m^3 of bark is present on harvested radiata pine trees prior to felling in Australia, and about 3.0 million m^3 is present in New Zealand. A significant portion of this bark is lost during normal handling as it progresses along the supply chain from forest to customer.

Bark acts a protective casing of the log reducing the risk of fungal infections (e.g. blue stain), soil contamination, and drying of the wood, thus contributing to a maintained log value. Since the inclusion of bark can be a serious problem in many forest product manufacturing processes, and may be a net financial loss to the forest industry (Marshall et al., 2006), it is normally removed before entering any type of wood processing mill. It can also be a phytosanitary risk for exported logs, necessitating removal or chemical treatment.

For over 40 years the utilisation of bark in Australasia has been of interest (Harris & Nash, 1973; Sands, 1974; NZTE, 2012). Hog fuel for energy, compost and landscaping products are currently derived from radiata pine bark, but potentially a wider range of bio-products is possible (Ferreira et al., 2015; Li et al., 2015). In some regions, however, energy and other markets for bark are of insufficient size to utilise all of the bark produced and so landfill dumping costs are incurred to get rid of the excess bark.

In a recent review of three New Zealand primary industry supply chains (Spanjaard & Warburton, 2012) – meat, forestry and wine – supply chain restructuring was a recommended approach for improving supply chain efficiency. Supply chain restructuring can be defined as a fundamental alteration in a supply chain

SATCO Eucalypt debarker
(www.satco.co.nz/satco-22-inch-debarker.html)

Pinus radiata logs being treated under cover with methyl bromide prior to export

affecting all functions and activities. The who, what, why, when, where and how questions are used to bring about improvements in the supply chain. Debarking logs in-forest (= where), i.e. towards the beginning of the supply chain rather than towards the end (= when), is an example of supply chain restructuring.

In 2015, the New Zealand Forest Growers Levy Trust funded a research project to quantify the potential costs and benefits of IFD of *Pinus radiata* and identify the maximum capital costs that could be paid for modified mechanised harvester/processor heads to debark logs. Additional funding was provided by the Toi Ohomai Institute of Technology, the University of the Sunshine Coast, and the Australian Forest and Wood Products Association.

Potential advantages and disadvantages of IFD

The following advantages are noted for IFD:

- The solid wood (m^3) content on weight-limited trucks can be increased if bark is removed. This can lead to reductions in transport costs and the number of trucks on the road that are required to transport a given volume of wood
- Fresh wood is about 50% water by weight. Removing bark increases drying rates and water loss (Defo & Brunette, 2006; Visser et al., 2014). If truck payloads are weight limited, reducing the amount of water in a log increases the solid wood volume that can be carried
- Bark takes up storage space. Removing bark improves solid wood volume storage in mill yards for the same storage footprint
- Assuming that debarking is an acceptable phytosanitary method for exported logs and that debarking can be carried out to an acceptable phytosanitary standard in-forest, fumigation costs can be reduced or eliminated
- Debarking costs for pruned wood at ports are eliminated if the logs are debarked earlier in the supply chain
- Solid wood volume storage at ports is improved. This also leads to reduced distances that wood is carried and potentially reduced handling costs
- If more accurate under-bark measurements can be gathered on harvesting/processing machines, there is an opportunity to revert to volume-based payment systems for harvesting and transport, thereby eliminating the need for weight-scaling systems and their costs
- Loose bark at ports is increasingly being seen as a marine contaminant. Eliminating bark before logs arrive at the port would reduce this environmental impact
- If bark is removed in the forest and left on-site as part of the nutrient pools there is a potential to reduce fertiliser costs
- Below-deck log export cargo is fumigated en route to the customer. Above-deck cargo has to be fumigated or debarked prior to loading. Fumigation is only carried out at a few ports in New Zealand. Where debarking is allowed as an alternative to fumigation, the need for ships to travel to a fumigation port to pick up above-deck cargo is eliminated with IFD, saving on port and shipping fees
- Collection, transport and disposal costs for bark waste in ports and mills are eliminated.

The following disadvantages are noted for IFD:

- Either an additional machine (and cost) is required for debarking in-forest or productivity is reduced and the cost increased for a harvester/processor that also has to debark logs
- If wood is sold to customers on a weight basis after it has been allowed to dry, additional solid wood (m^3) has to be sent to customers to replace the bark removed and water that is lost
- Forwarder loading time and log extraction costs may be increased due to handling slippery logs
- Truck loading time and transport costs may be increased due to handling slippery logs and attaching an extra tie-down per packet of logs
- Handling time and costs at mills and ports may be increased due to handling slippery logs
- Site preparation costs, resulting from clumps of bark left around landings, may increase if debarking is carried out on landings
- Larger landings, with consequent increased construction costs and environmental impacts, may be required to accommodate storage of logs for additional drying days
- Larger landings may be required to accommodate on-landing debarking for tree length harvesting systems

- Value losses due to sapstain may be increased as a result of a greater amount of bark being purposefully removed. It should be stressed that current harvesting systems already result in significant bark loss and that the value loss referred to here is the incremental value loss that would occur from IFD
- Increased value losses in tree length systems due to contamination from dirt and grit getting into the wood
- Reduced revenues from bark sales.

Methods

The models

Two economic models were developed within Excel spreadsheets that allowed quantification of the costs and benefits of IFD. The models span from forest establishment through to delivery of logs to mills or shipside. One model was volume-based, the other was weight-based, and the structure was similar for both models. They contained a summary worksheet that allowed inputs for key parameters (e.g. harvesting system, harvesting season, drying days, percent of harvest volume exported), and provided summarised outputs for revenues and costs for both IFD and non-IFD supply chains. Linking to the summary worksheet are eight worksheets that include wood and bark data, harvesting economics, transport economics, port economics, waste handling costs, additional shipping costs, other costs (e.g. site preparation, weighbridge scaling), and revenues from log and bark sales.

Data collection

The models were populated with data from bark loss trials and drying rate trials carried out in Australia and New Zealand, relevant published data, industry reports, and information supplied by industry personnel.

Data from 11 benchmarking studies allowed quantification of the amount of radiata pine bark lost during normal harvesting operations. Bark loss was related to harvesting season, harvesting system (e.g. tree length vs cut-to-length), mechanisation (e.g. manual vs mechanised delimbing and processing), harvesting activity (e.g. felling vs extraction), log position on the stem, and harvester head configuration (Murphy & Acuna, 2016). Additional bark loss data was gathered from two debarking feasibility trials; one carried out in Australia and one in New Zealand (Murphy, 2016).

Five log drying trials, to determine the effect of the presence of bark on drying rates, were carried out in Australia and New Zealand. Average drying rates were close to four times greater for Australia than New Zealand. Drying rate models were constructed for each country where the dependent variable was weight loss (kg), and the independent variables were initial weight (kg), harvesting season, and the amount of bark present on each log. More information on the drying rate trials and models can be found in Murphy (2016).

Base harvesting costs were obtained from mid-2016 Agrifax reports and recent production studies that the authors had been separately involved with in New Zealand and Australia. Base costs were proportionately allocated to harvesting activities (e.g. processing) based on a combination of experience and published production studies. An unpublished report (Informe Harvesting, 2013) prepared for STIMBR (Stakeholders in Methyl Bromide Reduction) by Forme Consulting Group Ltd was used as the basis for determining an indicative cost for IFD with a modified processor head; viz \$4.75 m^{-3}.

Base transport costs were obtained from mid-2016 Agrifax reports. These costs were adjusted based on any changes in payload, load handling time, and load securement time due to IFD. Costs for weight-scaling of logs, including maintenance of weight-volume scaling factors, were obtained from web-published weighbridge fees in New Zealand and updated costs from Smith (1978).

Base at-port costs for fumigation, debarking, log handling, scaling, storage and stevedoring were obtained from New Zealand companies associated with these activities. These costs were adjusted based on any changes in handling time, storage capacity and activities undertaken due to IFD.

Waste handling costs (collection, transport and disposal) of \$20.10 m^{-3} for bark that could not be utilised were obtained from a combination of analyses undertaken by Bayley (2009) and forest industry sources. It was assumed that 85% of bark generated at mills and 30% of bark generated at ports would be utilised.

Base costs for fertiliser, site preparation and landing construction were obtained from forest industry sources in the Bay of Plenty region of New Zealand. Adjustments for IFD were made based on expert opinion. A rotation length of 30 years and a yield of 650 m^3 ha^{-1} were assumed.

Additional shipping costs resulting from having to visit a port to pick up fumigated logs for above-deck cargo included additional port fees and delay-related shipping costs. It was assumed that the average ship volume was 30,000 JAS m^3 and above-deck cargo accounted for 30% of this volume.

Average export log prices and domestic log prices were obtained from mid-2016 Agrifax reports. Bark revenues of \$17 to \$22 m^{-3} were assumed for energy and landscaping products. Contamination losses due to dirt and grit were assumed to be 3.5% of revenue (Gerasimov & Seliverstov, 2010). Marginal sapstain losses due to IFD were assumed to only apply to domestic appearance grade logs, only occur in spring and summer, and reduce log value to pulp log prices. It was assumed that there would be no sapstain losses if logs were delivered to domestic mills in less than 10 days.

Scenarios and sensitivity analysis

Key parameters for the base case scenario for the New Zealand set of analyses are:

- Under-bark volume is 100,000 m^3

- Wood is harvested in summer by a ground-based tree-length system
- IFD is carried out by a separate machine at a cost of $4.75/m^3
- Logs are left for five days before being trucked to the customer
- IFD results in a 25% increase in truck loading time
- Truck payload is increased by 2.9% after IFD
- Mill yard debarking cost is $9/tonne
- 55% of the volume is exported, and 65% of the export volume is exported to China which allows debarking as a phytosanitary treatment
- Fumigation of above-deck logs is currently carried out at the port and costs $5.50/JAS m^3
- Port debarking cost is $5.50/JAS m^3
- An extra visit is required to the port to pick up above-deck cargo
- Some, but not all, bark generated at mills and ports can be sold (the remainder is dumped at a cost of $21/tonne)
- Additional sapstain values losses are 0% due to the short lead time between IFD and trucking to domestic customers
- Contamination value losses are 3.5% for tree-length harvesting systems
- IFD results in a 15% increase in site preparation costs.

The key parameters for the base case scenario for Australia are:

- Under-bark volume is 100,000 m^3
- Wood is harvested in summer by a cut-to-length system
- Logs are left for five days before being trucked to the customer
- 0% of the volume is exported
- Truck payload is increased by 8.3% (due to greater drying rates and more bark having to be removed in Australia than in New Zealand)
- IFD is carried out by a separate machine at a cost of $4.75/m^3
- Some, but not all, bark generated at mills can be sold (the remainder is dumped).

Sensitivity analysis was carried out for both New Zealand and Australian conditions by varying the values of key parameters.

Breakeven analysis for an IFD debarking head

The economic models were also used to determine the breakeven price for a processor head suitable for IFD. The IFD costs for the base case scenarios were increased to the point where the benefits became neutral. A breakeven price for a debarker head was then back-calculated based on standard costing procedures (LIRA, 1981).

Results and discussion

New Zealand scenarios

For the New Zealand base case conditions, there is a 3.2% gain in net revenue as a result of IFD, which is equivalent to $2.32/m^3. The sensitivity of these results to changes in key parameters is shown in Table 1.

If we use a change of $0.50/m^3 as a criteria for being sensitive or not, then we can say that the results are not sensitive to:

- Harvesting season
- The proportion of export volume exported to China
- Truck loading time adjustments or assumed increases in truck payload
- Fumigation costs
- Port debarking costs
- Bark waste disposal costs
- Additional site preparation costs
- Bark prices
- Whether a volume or weight-based analysis is carried out.

Pinus radiata logs that have been processed with a mechanised processor can end up with less than half of the bark remaining – in this case almost all of the bark has been removed

Table 1. Sensitivity of gain in net revenue to changes in key parameters for the NZ analyses

Parameter	Change	Gain in net revenue %	Gain in net revenue $/m³
Base case conditions		3.2	2.32
Harvesting season	Autumn	3.2	2.32
Harvesting season	Winter	3.2	2.30
Harvesting season	Spring	3.1	2.27
Harvesting system	Cable logging	4.3	2.78
Harvesting system	Cut-to-length	5.5	3.98
Drying days	Reduce to zero	3.5	2.58
Drying days	Increase to 10	0.1	0.05
Export %	Reduce to 45%	2.8	1.92
Export %	Increase to 65%	3.5	2.73
China volume %	Reduce to 55%	3.1	2.24
China volume %	Increase to 75%	3.3	2.41
Extra port visit	Not required	−0.5	−0.35
IFD cost, separate machine	Reduce to $3.80/m³	4.5	3.27
IFD cost, separate machine	Increase to $5.70/m³	1.9	1.37
IFD cost, single processing/debarking machine	Increase handling time by 75%	3.6	2.63
Loading time adjustment	Reduce to 20%	3.3	2.44
Loading time adjustment	Increase to 30%	3.0	2.21
Truck payload adjustment	Reduce to 1.8%	2.9	2.14
Truck payload adjustment	Increase to 4.0%	3.4	2.51
Mill debarking cost	Reduce to $7/t	2.0	1.47
Mill debarking cost	Increase to $11/t	4.4	3.18
Fumigation cost	Reduce to $4.40/JAS	3.0	2.22
Fumigation cost	Increase to $6.60/JAS	3.3	2.43
Port debarking cost	Reduce to $6.90/JAS	2.9	2.12
Port debarking cost	Increase to $10.30/JAS	3.5	2.53
Bark sales from ports	Increase bark utilisation to 60%	2.8	2.05
Waste disposal costs	Reduce to $17/t	3.1	2.29
Waste disposal costs	Increase to $25/t	3.2	2.36
Additional site preparation costs	Reduce to 10%	3.3	2.40
Additional site preparation costs	Increase to 20%	3.1	2.25
Interest rate	Increased to 5%	2.4	1.65
Daily shipping costs	Reduce to $15,000	2.0	1.51
Daily shipping costs	Increase to $35,000	4.4	3.14
Bark revenues	Increase all revenues by 20%	3.1	2.24
Sapstain losses; less than 10 days drying	Increase to 5%	0.1	0.05
Contamination losses	Reduce losses to 0%	5.4	3.92
Contamination losses	Increase losses to 7%	1.0	0.73

We can also say that the results are sensitive to:

- Use of cut-to-length harvesting systems
- Number of drying days (in spring and summer only)
- The proportion of volume that is exported
- Whether a ship has to visit a second port to pick up fumigated logs for above-deck cargo
- The assumed cost for a separate IFD machine
- Mill debarking costs
- The utilisation of bark generated at ports
- Daily shipping costs
- Sapstain losses
- Contamination losses.

The breakeven cost for IFD would be $7.07/tonne. At an assumed production rate of 300 tonnes/day, this equates to a daily cost of about $2,120. Subtracting labour costs of $260/day leaves $1,860/day to cover machine costs. This must cover the cost of the base excavator plus the cost of the debarker head.

A 35-tonne excavator costs about $990/day, leaving about $870/day to cover the costs of a debarker head. The ratios of daily cost to current purchase price for ground-based harvesting machines range between 0.0018 and 0.0021 (Informe Harvesting, 2013). Based on these ratios, and an assumed production of 300 tonnes/day, a breakeven cost for a debarker head would be somewhere between $410,000 and $480,000.

If the assumed production was only 250 tonnes/day, a breakeven cost for a debarker head would be somewhere between $245,000 and $285,000. These breakeven costs compare with reported costs for processor heads of $270,000 to $300,000 (Informe Harvesting, 2013).

Australian scenarios

For the Australian base case conditions there is a 9.5% gain in net revenue as a result of IFD, which is equivalent to $4.25/m³. The sensitivity of these results to changes in key parameters is shown in Table 2.

If we use a change of $0.50/m³ as a criteria for being sensitive or not, then we can say that the results are not sensitive to:

- Harvesting season
- Truck loading time adjustments or assumed increases in truck payload
- Bark waste disposal costs
- Bark prices.

We can also say that the results are sensitive to:

- Number of drying days
- The assumed cost for a separate IFD machine

- Mill debarking costs
- Utilisation of bark at mills
- Sapstain losses.

The breakeven cost for IFD would be $9/tonne. At an assumed production rate of 300 tonnes/day, this equates to a daily cost of about $2,700. Using the same method as was used for the New Zealand scenario and an assumed daily production of 300 tonnes, a breakeven cost of somewhere between $690,000 and $800,000 would be calculated for a debarker head. If the assumed production was only 250 tonnes/day, a breakeven cost for a debarker head would be somewhere between $475,000 and $555,000.

Table 2. Sensitivity of gain in net revenue to changes in key parameters for the Australian analyses

Parameter	Change	Gain in net revenue	
		%	$/m³
Base case conditions		9.5	4.25
Harvesting season	Autumn	9.3	4.18
Harvesting season	Winter	9.0	4.06
Harvesting season	Spring	9.7	4.32
Drying days	Increase to 10	−12.7	−5.70
Drying days	Increase to 20	−11.9	−5.42
IFD cost, separate machine	Reduce to $3.80	11.6	5.20
IFD cost, separate machine	Increase to $5.70	7.4	3.30
Loading time adjustment	Reduce to 20%	9.7	4.36
Loading time adjustment	Increase to 30%	9.2	4.14
Truck payload adjustment	Reduce to 6.6%	8.8	3.96
Truck payload adjustment	Increase to 10.0%	10.1	4.54
Mill debarking cost	Reduce to $7.20/t	5.5	2.54
Mill debarking cost	Increase to $10.80/t	13.8	5.96
Waste disposal costs	Reduce to $16.80/t	9.4	4.22
Waste disposal costs	Increase to $25.20/t	9.6	4.28
Bark use for energy at mills	Reduce to 64%	10.8	4.79
Bark use for energy at mills	Increase to 95%	8.3	3.75
Bark revenues	Increase by 20%	8.8	3.99
Sapstain losses; less than 10 days drying	Increase to 5%	−1.8	−0.80

Limitations and conclusions

During the time that this research was undertaken a purpose-built debarker head, capable of debarking radiata pine, had not been developed. Development by one processor head manufacturer has since begun. Debarker feasibility trials were therefore carried out in Australia and New Zealand by the authors, and prior to that by Forme Consulting Group Ltd, using either eucalypt debarker heads or conventional processor/harvester heads. The feasibility trials indicated that IFD to phytosanitary standards could be achieved for some log grades and that a modified processor head could be competitive with methyl bromide fumigation.

However, similar to ring debarkers used on or off-port, some logs (particularly smaller head logs and rougher logs) might fail phytosanitary inspection due to bark remaining around branches, fluted areas, in forks etc. Such logs may require additional treatment for export. The feasibility trials did not give a good indication of likely productivity from a purpose-built pine debarker head operated by a skilled operator.

Having stated this limitation, for both Australia and New Zealand it would appear that IFD may be an economically viable alternative to debarking further along the supply chain. The potential gains for Australia are larger than those for New Zealand mainly due to their:

- Greater use of cut-to-length systems, which tend to retain greater quantities of bark in comparison to tree-length systems, and they carry the logs (thereby reducing contamination losses), and
- Faster drying rates for debarked logs.

New Zealand tends to benefit from reduced fumigation costs and multiple-port visiting costs.

Breakeven capital costs for a debarker head were calculated to be a minimum of $245,000 for New Zealand and $475,000 for Australia.

It should be noted that the economic viability of IFD was very sensitive to the assumed additional value loss associated with sapstaining when logs were left to dry for 10 days or less. A 5% value loss associated with sapstaining would reduce the net revenue gain to almost zero for New Zealand and to less than zero for Australia. The implications of this for both countries is that the breakeven cost for a debarker head would be substantially lower than the current cost for a small processor head (ranging from less than $0 to as much as $105,000). Further effort should be put into quantifying value losses due to sapstain.

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