Forest-mill Integration from a Transaction Costs Perspective

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Master of Forestry Science

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Fibre sourcing is a critical strategic question for all sawmills and pulpmills, but the degree of supply integration though long-term contracts and forest ownership varies widely. The purpose of this research was to investigate the extent to which forest-mill integration patterns can be explained by the transaction cost economics (TCE) theory.

TCE theory holds that organizations will choose transaction governance forms that minimize transaction costs. The TCE factors expected to influence that choice can be grouped into three categories; transaction frequency, market uncertainty, and asset specificity. Interviews with various industry representatives suggested that factors from all three categories are relevant to the question of forest-mill integration.

A survey was conducted of mills in New Zealand and Sweden, providing data on their supply mix and various TCE factors. Of an estimated population of approximately 450 mills, 136 mills were sampled and 88 responded to the survey. Fractional logit models were developed to explore the factors that may influence the integration decision.

Considerable evidence was found for the importance of TCE factors in driving fibre supply integration. The evidence was strongest for factors related to asset specificity, including forest owner concentration and the specificity of a mill’s fibre requirements. Transaction frequency appears less important; while integration was found to be significantly associated with the number of mills an organisation has within the supply basin, the influence of mill capacity was found to vary. There was weak evidence for the importance of uncertainty, and perhaps only through the impact of forest owner concentration on market conduct.

Integration was found significantly higher for pulpmills than sawmills, and higher in Sweden than in New Zealand. The latter result is difficult to explain by TCE theory, and suggests that non-TCE factors play a significant role. Survey responses also indicated that non-TCE factors are important. Further research is required to enlarge the sample size and better understand the role of TCE factors in forest-mill integration.

1 INTRODUCTION

Fibre sourcing is a critical strategic question for sawmills and pulpmills globally, because fibre represents a very large share of their production costs. Historically, the larger players have tended to own forests to secure fibre supply. Separation of forest and mill asset ownership is now becoming more common in several parts of the world. Surprisingly few studies have investigated the drivers of forest-mill integration decisions.

The theory of transaction cost economics (TCE) has been found very powerful in explaining diverse integration questions. TCE theory holds that exchange agreements must be governed, and that the exchanging parties will try to adopt governance forms that minimise transaction costs. Possible governance forms span the range between complete reliance on the market to full internalization of the transaction (integration), where intermediate forms often involve some form of contracting.

The following sections provide an introduction to the question of forest-mill integration, outlines prior research on the topic, and presents the research objective.

1.1 Research objective

The objective of this research was to test TCE theory with respect to forest-mill integration in New Zealand and Sweden. There has been concern within the New Zealand forest industry that a lack of investment in downstream processing may be due to low levels of consolidation and integration. Sweden provides a good comparison in this respect, because it has a very well-developed forest products sector. In addition, the trend towards forest and mill asset separation is relatively new in both countries, and the question of whether this development is driven by concerns for economic efficiency is highly interesting.

1.2 Forest-mill integration

Fibre is the key input factor for sawmills and pulpmills. Sawlogs typically represent 60-80% of sawmill's operating costs[1] (Poyry, 2003 and Poyry, 2005). Fibre, usually in the form of pulplogs or wood chips, represents 40-60% of production costs for bleached kraft pulp, and is the single largest cost factor (Poyry, 2005 and NZIER, 2001). For this reason, procurement of fibre is a very important part of these businesses' strategy and operations. Access to reliable and low-cost fibre can represent an enormous competitive advantage.

In practice, mills can source fibre from their own forests, through supply contracts, or from the open market. Most mills meet their fibre needs through a combination of all three sources, but the relative share varies greatly.

Historically, the larger players in the world's forest-products economies (including North America, Scandinavia and Australasia) have tended to own forest for much of their fibre needs. The reasons for this are many and will be discussed in detail, but security of supply is clearly an important factor, given the continuous manufacture process and high capital intensity of the processing industry.

However, over the last few decades there has been a trend towards separate ownership of forest and downstream assets. This started in the US in the 1970s, and most of the forest products companies there have now sold their forest assets; of the largest 10 forest owners in the US, only two have downstream operations[2]. This trend has even been apparent in Scandinavia and Australasia, although more recently and to a lesser extent[3].

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[1] Including fibre, labour , energy, and delivery, but excluding capital cost and overhead

[2] Weyerhaeuser and Temple Inland

[3] Some examples of this are a) Stora Enso's sale of their Finnish forest assets to a group of investors in 2002; the first securitisation of forestland in Europe, forming the company Tornator, b) Korsnäs and Stora Enso's sale of their Swedish forest assets in 2004 to Bergvik Skog, c) Carter Holt Harvey's sale of its New Zealand forests to Rayonier and Deutsche Bank in 2005, and Hancock in 2006, d) Fletcher

1.3 Prior research

Research on the factors that influence the forest-mill integration decision has focused on the North American industry, and few have considered TCE. According to Binkley et al. (1996), the sale of forest assets by forest product companies in the US was due to two independent forces:

1. Changes in the regulation of the pension and life insurance industry encouraged diversification of investments, and institutional investors became interested in forest assets.
2. Forest products companies started reassessing the benefits of forest ownership. Many concluded that forest assets were undervalued by the stock market and should be divested. At the same time, improvements in harvesting and transport efficiency meant that supply basins were enlarged, increasing security of supply.

Yin et al. (2000) studied the effect of forest ownership on operating decisions for a paperboard mill. They presented three key features of the pulp and paper industry, which make integration attractive: the industry has (1) *high capital intensity*, and (2) a *high degree of asset specificity*[4], which together yield a lack of flexibility and vulnerability to the (3) *highly cyclical markets*. These factors are all central to TCE theory, but the objective of this research was not to test how they influence integration decisions. Rather, they analysed the value of integration to an organisation in terms of increased stability of costs and revenues.

Yin et al. modelled the operating decisions (entry, exit, mothballing, and reactivation) for a hypothetical linerboard mill in the U.S., with respect to market linerboard prices and timberland ownership. The model showed that there are threshold prices for each

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Challenge's sale of its New Zealand forests in 2003 to different investors including Harvard University, Prudential Timber, Kiwi Forests Group, and Ontario Teacher's Pension Plan

[4] Reflected in the fraction of asset's value that would be lost if it were excluded from it's major use

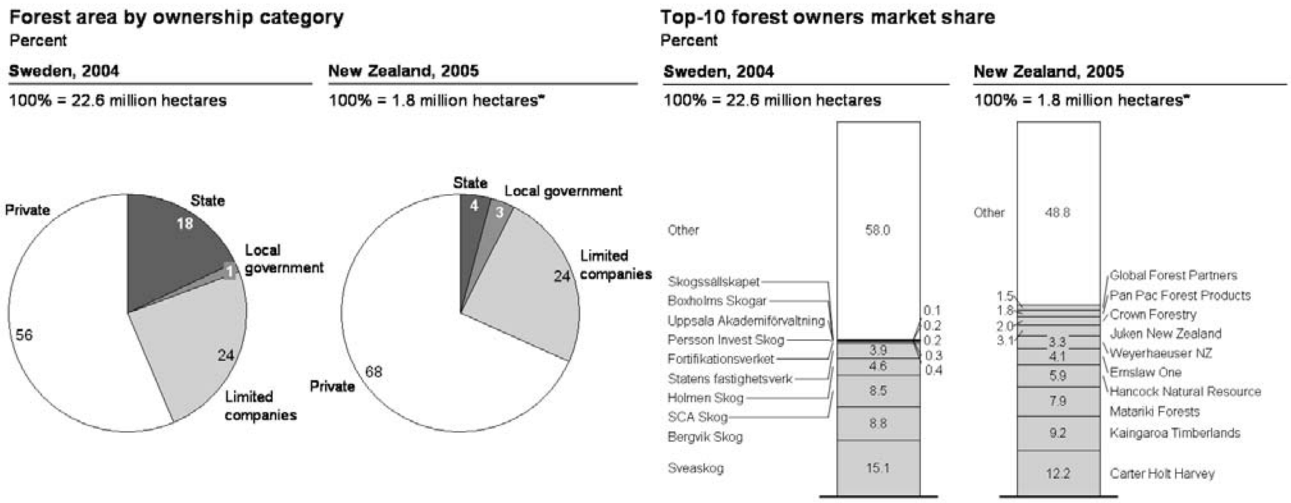
decision, and that these thresholds are lower when the mill is integrated, assuming a cost-based transfer price for forest fibre. The authors suggest that integration creates supply flexibility and more stable cash-flows, thereby allowing better long-term investment decisions. It may also be argued that the transfer of profits from a forestry operation to a paper operation (which might not be value-creating on its own) does not maximise the value of the forest asset, and may not be considered a viable reason for integration by all investors.

There is evidence to suggest that TCE could be relevant to the forest integration decision. In their study of vertical integration in the Canadian forest products industry, Globermann and Schwindt (1986) concluded that transactional considerations are important determinants of governance structure. Their approach was to examine the structure of companies' entire value chains, searching for transactions that are inconsistent with TCE theory. They found very few anomalies. All but one of the largest 30 companies owned timberland cutting rights, and they attributed this to transaction costs.

Globermann and Schwindt (1986) suggested that sawmills and pulpmills are dedicated to a specific forest basin defined by the economic transport radius for logs, because mills are not easily relocated (salvage values are low relative to the cost of initial construction). They argue that forests are not as dependent on a particular mill, because standing forest is not a wasted asset. In the event of no transaction, forest owners have the alternative of letting the forest continue to grow. Mills that need a continuous supply of logs are vulnerable to opportunistic behaviour from independent suppliers, and this encourages integration.

However, the Canadian case is somewhat special; 93% of forestlands in Canada are state-owned, and it is unclear whether the high level of integration is due to TCE factors or the institutional framework imposed by the government. Cutting rights are assigned in accordance to the provincial forest acts. Canadian forest products companies that want to gain rights to public timber have needed to build or operate a mill, and the timber rights are tied to this mill through an appurtence agreement.

Figure 1: Forest ownership in Sweden and New Zealand



* Plantation forests only

Source: NZFOA/WPA/MAF, “NZ Forest Industry Facts and Figures”, 2007; Swedish Forest Agency, “Yearbook of Forestry”, 2007

In contrast, forest-mill integration in Sweden and New Zealand is very much an open question, because commercial forest ownership is largely private and much more fragmented (refer to Figure 1). These countries provide interesting case studies for the role of TCE in forest integration.

2 THEORETICAL FRAMEWORK

The theory of transaction cost economics is well developed, by Williamson (1975; 1979), Klein, Crawford and Alchian (1978), Grossman and Hart (1986), and Hart and Moore (1990) among others. It has been applied to a wide range of disciplines where problems of contracting and economic organisation emerge, including economics and business, law and public policy (Boerner and Macher, 2001). It has also become widely applied in business strategy (Stuckey and White, 1993).

The following section summarises the theoretical framework used in this research, including an introduction to TCE theory, support for the theory, and challenges in TCE research.

2.1 Introduction to TCE theory

In short, TCE theory holds that exchange agreements must be governed, and that the exchanging parties will try to adopt governance forms that minimise transaction costs. Often the choice of governance form can be simplified to the “make versus buy” decision, meaning the choice between market and hierarchical governance (Sykuta, 2005). However, a range of intermediate solutions can exist between buying on the spot market and full integration, including long-term contracts, strategic alliances, and joint ventures (Williamson, 1991 and Menard, 2004).

A key determinant of transaction costs is the risk of hold-up. This is opportunistic behaviour by one party in the transaction to their own advantage, and to the disadvantage of the other party. Hold-up can increase transaction costs in several ways:

1. The risk of hold-up actually occurring, and the subsequent losses incurred
2. Payment of a premium to discourage opportunism
3. The cost of writing, monitoring, and enforcing long-term, complex contracts

Two key factors determining the risk of hold-up are the level of *asset specificity* and the level of *uncertainty* (Stucky and White, 1993).

Asset specificity impacts the size of “appropriable quasi-rents”; the potential gain available through the hold-up. In simple terms, these rents are equal to the difference between the value of the agreed transaction, and the value of next best alternative (Klein et al., 1978). For example, if a buyer’s asset is highly specific to a particular input, the asset’s value would be greatly diminished if the supply of that input was disrupted. Therefore the appropriable quasi-rents are large, and the supplier could gain considerably by threatening to cease supply. Common forms of asset specificity include the proximity of the supply source to the processing asset, the customization of the asset and human resources to the supply source, and supplier concentration.

High levels of uncertainty in a market can increase the risk of hold-up, due to the need for frequent re-negotiation of terms. Alternatively, uncertainty can increase the costs of preventing hold-up by making the process of designing comprehensive contracts more complex, and the required price premium higher (Klein et al., 1978).

An additional transaction-cost factor that is not directly related to the risk of hold-up is transaction frequency (Williamson, 1979). This is of great importance for the choice of exchange governance form, because total transactions costs are a function of costs per transactions and the frequency of transactions. For example, parties with large-volume or frequent transactions have greater incentive to lower their unit transaction costs through integration.

2.2 Support for TCE theory

Research in a wide variety of fields has shown that transaction cost theory can help understand all type of vertical integration decisions. Boerner and Macher (2001) provide a comprehensive review of TCE research in fields as varied as organisation theory, international business, law and public policy, and agricultural economics.

TCE theory has been quite well tested in the forest products industry, but mainly with regard to integration of pulp and paper production, not forest-mill integration. Ohanian

(1994), Melendez (2002) and Wang (2005) have all shown that transaction cost factors have an important role in determining the degree to which paper mills have integrated pulp production versus buying pulp from other producers. However, these studies used publicly available information on a few mill parameters, especially capacity, grade mix, and derived estimates for regional concentration. They were therefore limited by the data source in the breadth of TCE factors that could be tested, with the associated risk of exclude
ing important factors.

Ohanian (1994) studied the integration of pulp and paper manufacture in the US between 1900 and 1940, with respect to four variables. These were market concentration (measured as the product of the market shares of the largest four producers in a given region, by capacity), the logarithm of paper capacity, and the proportion of capacity that was newsprint and kraft paper respectively (integration was hypothesised to be higher in production of these grades, due to a relatively low level of specialisation). She found that integration was positively and significantly associated with all four variables, and concluded that transaction costs appear to influence integration. The evidence was particularly strong for new mills, because few mills switched between integrated and non-integrated once established. Ohanian recognised however that the narrow selection of variables may have led to important variables being omitted.

Melendez (2002) argued that integration in pulp and paper was influenced by a mill characteristic not observed in previous studies: mill productivity determines whether mills remain in use, and whether they are integrated. She used the same data as Ohanian (1994) but for 1975-1995, and chose a dynamic model in order to eliminate the problem of selection and simultaneity bias arising from mills entering and exiting the industry. Melendez also found that integration was positively associated with mill capacity and grade specialization, but in contrast to Ohanian (1994) she found that it was negatively associated with market concentration. It seems that market concentration was endogenously determined, and therefore yielded biased estimates in the model[5].

Wang (2005) attempted to clarify the role of market concentration in pulp and paper integration. He used a mill-specific concentration measure (a Herfindahl-Hirschman Index for seller and buyer market respectively within a set radius from the mill, excluding mills owned by the same firm) and focused on uncoated freesheet (a paper grade where non-integration is still relatively common). Wang also used a dummy for region in order to control for the impact of forest abundance on concentration and integration[6]. With these refinements, he was able to show a significant positive relationship between market concentration and integration.

As discussed in section 1.3, Globermann and Schwindt (1986) studied transaction governance structures in the Canadian forest products industry, and found very few anomalies with TCE theory. However, in the case of forest-mill integration, the high level of integration could also be explained by the process of allocating cutting rights. Also, the findings were somewhat anecdotal, based on observed integration patterns and speculation about how TCE theory could explain those patterns.

TCE theory has also been shown useful in understanding forest companies' choice of contractual forms and payment for silvicultural operations. Wang and van Kooten (1998) studied companies' decisions to contract out silvicultural activities or perform these in-house, with respect to various firm and activity attributes. The work was based

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[5] During 1900-1940, the US paper industry expanded into the South, and the new mills were typically large and integrated for long-term competitiveness (there are significant efficiencies of scale in paper production, and market pulp tends to cost more than integrated pulp due to costs of drying and transport), while the abundant forests in the region made it possible to build large integrated mills. The small number of mills in the region meant a high concentration measure, and hence the positive association of concentration with integration in Ohanian's (1994) model. By 1975-1995, the difference in market concentration in the US regions had narrowed and Melendex (2002) could not find the same relationship.

[6] Wang (2005) argued that, at least in a migratory industry, regions with abundant forests would likely be colonized by new, integrated mills. This would result in both high concentration and high integration, contrary to the predictions of TCE theory, unless forest abundance was controlled for.

on data from a survey of forest companies in British Columbia, including details of 697 recent operations, and participants' ratings of transaction cost attributes for the most common types of attributes. They tested both a probit model (where decisions were categorised as out-sourced or any in-house performance) and an ordered probit model (where a decision was represented as out-sourced, a combination of both forms, or fully in-house), and found that the TCE factors were highly significant. In particular, firms are more likely to perform the operations in-house if they require a high degree of technical skill or must be performed often.

Using data from the same survey, Wang et al. (2000) focused on how silvicultural workers are paid; with piece-rates or time-based payment. The hypothesis of the research was that managers chose the payment scheme that minimizes transaction costs, and that the costs depend on the characteristics of the firm and the silvicultural activity. An important cost in such transactions (the purchase of labour) is shirking; on quantity where time-based payment is used, and on quality with piece rates. The relative importance of quality and quantity, and the difficulty of monitoring each, were expected to be key considerations. They used both a probit model (for the dichotomous choice of piece-rate or time-based payment) and an ordered probit model (for the polychotomous choice of piece-rate, hourly wage, or salary). The results indicated that piece rates are preferred by smaller firms, and for basic silviculture where operations are highly standardised. Time-based payment was preferred by larger firms, and for enhanced silviculture where quality is paramount.

There is further research the importance of TCE in other commodity industries that provides some clues on what factors could influence the forest-mill integration. These include Hobbs' (1997) study of cattle marketing and MacInnes' (2003) study of retail and wholesale marketing of organic farm produce.

Hobbs (1997) looked at the factors influencing UK farmers' decisions to sell cattle by auction or direct-to-packer, where the former channel is closer to the market transaction model than the latter, on a market-integrated scale. The research was based on survey data on very diverse variables, analysed with a tobit regression model. Hobbs found strong support for the importance of transaction cost factors in affecting this decision. The factors that seemed to encourage direct-to-packer sales were the time farmers must spend travelling to and attending auctions, the risk that the cattle may not sell at the auction, the average number of cattle in a sale lot, and farmers' satisfaction with packer procurement staff. Price uncertainty from selling by auction did not have any significant influence on the decision.

MacInnes (2003) studied organic farmer's access to indirect markets (retail and wholesale intermediaries), where the alternative is the direct sale of own produce. He used data from a nationwide survey of US organic farmers, including variables on market, farm and socioeconomic parameters, analysed with both tobit and logit regression models. The results supported the importance of several TCE factors from all three categories. For example, access to indirect markets and oversupply of organic produce were associated with greater use of indirect channels, while distance to market, failure of buyers to honour commitments, access to direct "farmer's" markets, and the number of different products sold were associated with a higher degree of direct sales.

2.3 Challenges in TCE research

The two key challenges for all empirical TCE research are data availability and the measurement of TCE factors. Other issues cited are the need for a more formal theoretical foundation, and the treatment of endogenous explanatory variables (Sykuta, 2005, Boerner and Macher, 2001).

Boerner and Macher (2001) found that "the most common means of primary data collection in empirical TCE research are mail surveys, interviews and firm visits". While primary data collection is relatively costly, and this often leads to small sample sizes, it can be the best approach to obtain useful data. Secondary data sources include industry registers and trade publications. These contain predefined datasets, often with insufficient detail, that allow researchers little room to derive appropriate measures for integration and its drivers.

Data limitations can be a reason for difficulties in measuring TCE factors. Exact measurement of asset specificity and uncertainty is usually not possible, but relies on proxies. For example, Ohanian (1994) and Wang (2005) used regional asset concentration as a measure of asset specificity. Other proxies commonly used for asset specificity include geographic proximity, employees' own ratings, and advertising or research and development intensity (Boerner and Macher, 2001). Such proxies may not always be good measures of the size of the quasi-rent, and thereby the risk for opportunistic behaviour. Besides data limitations, Sykuta (2005) argues that the poor definition of theoretical concepts in TCE is also to blame.

Boerner and Macher (2001) call for a more formalised theoretical foundation, which would allow more precise definition and testing of TCE factors. TCE theory suffers from multiple and even competing definitions of concepts, such as uncertainty. Uncertainty is commonly defined either as environmental (referring to state-changes in the circumstances surrounding the exchange) or behavioural uncertainty (for example, strategic nondisclosure or distortion of information). Boerner and Macher (2001) found that TCE research has conflicting findings regarding the role of uncertainty in the choice of transaction governance, and suggest that greater conceptual clarity would help.

Finally, an issue raised by both Syutka (2005) and Boerner and Macher (2001) in their reviews of empirical TCE research is endogenous transaction cost variables. It is common to treat variables, such as asset specificity, as exogenous (i.e. environmental factors that influence the choice of governance form) whereas they can be choice variables within a firm manager's control. Care should therefore be taken to identify which variables are endogenous.

3 RESEARCH METHODOLOGY

The method chosen for this research was to survey sawmill and pulpmill managers to ascertain the mill's level of integration in fibre supply, and the mill-related factors that could influence this decision. The latter included both known transaction cost factors and other suspected drivers. Integration was measured as the percent of total fibre needs that come from own forests, long-term contracts, and the open market. A survey was chosen as the best approach, because information on many of the most important factors is not available from public sources. The survey data was complemented with public data where available.

The following section outlines the methodology applied to survey design, survey execution, and data analysis.

3.1 Survey design

There were several steps involved in designing the survey including the review of similar surveys from other industries, interviews with contacts in the industry, distributing the draft survey for feedback, and incorporating the feedback.

1. Review of similar surveys from other industries

The studies that were of most use in designing the survey for this research were Hobbs' (1997) study of cattle marketing, MacInnes' (2003) study of retail and wholesale marketing of organic farm produce, and Antaniori and Rausser's (2001) study of community forest ownership in Mexico.

2. Interviews with contacts in the forest products industry

At an early stage in the research, informal interviews were conducted with colleagues in the forest products industry, and other representatives of forest and mill owners. The objective was simply to hear their opinion on what the most important factors are that influence forest-mill integration. Many of the learnings from these interviews are reflected in section 4, “TCE factors in fibre sourcing”. An interesting finding was that many of the factors considered important have nothing to do with TCE theory, such as company history and identity, perceived rate of return on forest assets, and the need to free capital. This was explored further in the survey.

3. Review of draft survey

Once a survey was drafted, it was circulated among colleagues, industry and academic contacts. These included consultants to the forest product industry, researchers in the fields of forest economics and industrial economics, my supervisors and their colleagues. The purpose of the review was to ensure that the survey was valid from a technical perspective, and that the questions were clear and answerable.

This review provided a lot of valuable feedback, such as the need to shorten and simplify the survey in order to increase response rate. Another useful discussion was the appropriate radius for defining the economically viable limit for transporting logs and chips to the mill. This is important when ascertaining asset specificity. There is no common definition for fibre basin radius, but it depends on the transport network and value of a given fibre grade. One option considered was to allow respondents to define the size of their fibre basin, but this could have introduced a bias that was difficult to control for. Instead, a constant definition was used, reflecting the typical radius for each of the two regions. According to information from the Swedish Forest Agency (2007) and New Zealand Ministry of Forestry (1997, 2001), an average distance of 90-100 km is typical for fibre transport in both countries. A radius of 120 km was therefore considered appropriate to describe the full fibre supply basin.

4. Designing the final survey

Four surveys were designed, one each for sawmills and pulpmills, and in both English and Swedish. The translations were done in a way that would minimize the potential for differences in interpretation, and they were reviewed by those contacts in step (3) that speak English and Swedish.

The only difference between the surveys for sawmills and pulpmills was that the latter required questions covering the use of wood chips in addition to logs, and some questions were omitted because the information could be obtained from public sources. Pulpmills can use wood chips and other residues from sawmills, in addition to pulplogs. The two are substitutes, but chips are generally cheaper and of lower quality. In the case of pulpmills, the level of integration in chip supply might influence the integration of log supply. The questions omitted from the pulpmill surveys were on mill capacity and capacity by grade category, both of which are available from NLK Associates' global pulp and paper mill database. The final surveys are included in Appendix 4.

3.2 Survey execution

Survey execution involved four steps; identifying the mills in each region, selecting a random sample of mills, distributing the survey, and data collection.

1. Identifying the mills in each region

Lists were compiled of the sawmills and pulpmills in each region, from a variety of sources. The NLK Associates database was used to identify pulpmills, including both integrated and market pulp capacity. Swedish sawmills were identified using lists from the Swedish Forest Industries Federation and the Swedish Forest Agency. For New Zealand sawmills, lists from the NZ Ministry of Forestry and NZ Timber Industry Federation were used.

2. Selecting a random sample of mills

A random sample of mills from each group was selected. The population, sample size and response rate by group are summarised in Table 1. A sample size was chosen that should provide a strong base for analysis and statistically significant results, allowing for non-responses. All six pulpmills in New Zealand were sampled.

Table 1: Summary of sample rate and response rate

Group	Population	Sample	Sample rate	Responses	Response rate
Sawmills, Sweden	200	50	25%	32	64%
Pulpmills, Sweden	38	30	79%	23	77%
Sawmills, New Zealand	212*	50	24%	28	56%
Pulpmills, New Zealand	6	6	100%	5	83%
Total	456	136	30%	88	65%

* Phone interviews suggest that many of these mills are closed or portable (excluded from the study), so the actual sample population is probably much smaller

Telephone directories[7] were used to cross-check the lists and obtain contact details. The target participants were mill managers (or procurement managers if that role existed). All sampled participants were called and spoken to directly, in order to explain the purpose of the survey, ascertain the most appropriate mill employee to answer the survey, and obtain buy-in from participants. In some cases, the identified employee indicated at this point that they did not want to participate in the survey. These mills were counted as non-responses.

3. Distribution of survey

The surveys were internet-based, using an internet survey service called SurveyMonkey[8]. After calling the participants, a link to the survey was sent by email, together with a mill-specific user code for identification of each mills' results. The email also included further information on the purpose of the research.

4. Data collection

Each participant's response was stored automatically on SurveyMonkey's database, where it could be downloaded at any time. The responses were supplemented with publicly available data, and participants contacted for clarification where necessary.

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[7] http://gulasidorna.eniro.se and http://yellow.co.nz

[8] http://www.surveymonkey.com

3.3 Econometric analysis

The dependent variable in TCE research is often a self-sufficiency ratio, the proportion of supply that is integrated. Two types of models are typically used for proportions as the dependent variable; the two-limit tobit and fractional logit.

Tobit is a linear regression model for continuous censored dependent variables, such as proportions bounded by 0% and 100%, described in Greene (2003, p 764-773). It uses a latent variable y* and estimates the distribution of y* unconstrained by the censor boundaries. The two-limit tobit model is specified as follows:

$$y^* = x\beta + \mu$$
$$y = \begin{cases} L_1 & if \;\; y^* \le L_1 \\ y^* & if \;\; L_1 \le y^* \le L_2 \\ L_2 & if \;\; y^* \ge L_2 \end{cases} \tag{1}$$

where y^* is the latent variable (the level of supply integration), x is the vector of independent variables, μ is the error term, L_1 and L_2 are the lower and upper limits respectively.

The likelihood function for the tobit model is

$$L(\beta,\sigma | y, x, L_1, L_2) = \prod_{y=L_1} F\left(\frac{L_1 - x\beta}{\sigma}\right) \prod_{y=y^*} \frac{1}{\sigma} f\left(\frac{y - x\beta}{\sigma}\right) \prod_{y=L_2} \left[1 - F\left(\frac{L_2 - x\beta}{\sigma}\right)\right] \tag{2}$$

where *F* is the normal cumulative function, and *f* is the normal density function.

The tobit model is commonly applied to TCE problems (Sykuta 2005, Hobbs 1997, MacInnes 2003). However, there are two important drawbacks of the tobit model. Firstly, the validity of the tobit model depends on two important assumptions; the error term must be homoskedastic and normally distributed. Secondly, while it may be suitable for data *censored* by two limits, it may not be appropriate to apply to data *defined* within those limits (Maddala, 1991). Self-sufficiency proportions of 0% or 100% would be assumed to represent missing (censored) variables. They are however real observations, not missing or censored per se.

The fractional logit model was developed by Papke and Wooldridge (1996), specifically to deal with proportions data. It has also found use in TCE research, for example by MacInnes (2003). The model does not have the drawbacks of the tobit model, and is preferable for this analysis.

The fractional logit model is an extension of the logit model, given by:

$$E(y|x) = e^{x\beta} \big/ \left(1 + e^{x\beta}\right) \tag{3}$$

The model is estimated using the quasi-maximum likelihood function

$$L(\beta \mid 0 < y < 1, x) = \prod_{i=1}^{n} \left[G(x_i\beta)\right]^{y} \left[1 - G(x_i\beta)\right]^{1-y} \tag{4}$$

where $G(x\beta) = e^{x\beta} \big/ \left(1 + e^{x\beta}\right)e$

An important advantage of the fractional logit model is that while it assumes a logistic distribution, the model is consistent with alternative distributions. It is therefore not necessary to test whether the logistic distribution holds in order to obtain statistically reliable results

4 TCE FACTORS IN FIBRE SOURCING

As discussed in chapter two, TCE theory has been used to help understand contracting and economic organisation in a wide range of situations, but rarely forest-mill integration. The following chapter provides a discussion of the TCE factors that are likely to influence the forest integration decision. This is based on the application of TCE theory to other industries, interviews with contacts in the industry, and own experience. According to TCE theory, transaction frequency, uncertainty, and asset specificity are likely to influence the integration decision.

4.1 Transaction frequency

Transaction frequency can be measured simply as the volume of fibre consumed in a given period. This is clearly related to the mill capacity. Larger mills should be more likely to source more of their fibre needs from own forests, due to scale effects (the total saving made through internalising the fibre purchase transaction are larger relative to the fixed costs of forest ownership). Companies with several mills in the same fibre basin, and thereby greater fibre needs, will also have increased incentives to own forest.

4.2 Uncertainty

Uncertainty in terms of price volatility and the likelihood that the mill can meet its fibre needs should impact the cost of buying on the open market and through contracts. Fibre prices tend to be volatile due to their sensitivity to unforeseeable factors such as harvesting conditions, storm events, and forest health. Fibre markets tend to be local, due to log and chips' relatively low value to volume ratio, and thereby high transportation cost. For this reason, price rises cannot always be passed onto the mill's customers, which may be sourcing from mills in several distinct fibre markets. As discussed in section 2.1, contracting costs also increase with uncertainty.

4.3 Asset specificity

It is perhaps the forest product industry's level of asset specificity makes it most unique. The adaptation of a mill to its fibre basin, the enormous variety in fibre grades and the profound impact these have on mill products, and the limited potential to relocate a mill all lead to very high levels of asset specificity.

Asset specificity can take several forms, which will be discussed separately:

1. Buyer and supplier concentration
2. Site specificity
3. Technical specificity
4. Human capital specificity

4.3.1 Supplier and buyer concentration

The concentration of suppliers and buyers determines the number of potential transaction partners, and thereby a mill's bargaining power and supply security. Markets with few buyers and sellers are likely to fail entirely. The cost of the transaction through market mechanisms is too great, and the transaction is therefore internalised (integrated).

Ceterus paribus, in a market with fewer suppliers the suppliers will have increased bargaining power. In such markets, a mill should have greater incentive to integrate. In markets with few buyers and many suppliers, the buyers have a strong bargaining position and are less likely to integrate. The suppliers (forest owners) could then gain through integrating forwards, but are typically too small to do so.

Forest ownership and the downstream processing industry tend to be very fragmented, and this is certainly the case in New Zealand and Sweden. However, fibre markets are relatively local and there is considerable variation in concentration by fibre basin.

The surveys captured concentration with questions on the supply/demand share of the top three suppliers/consumers. Another way to measure concentration would be the total number of suppliers a mill has, but a limited number of actual suppliers might not indicate a shortage of alternative suppliers. The mere presence of alternative suppliers gives the mill a sense of supply security

Forest owner associations could impact the cost of fibre in two ways:

1. Raising costs through increasing supplier concentration and bargaining power.
2. Lowering costs by more coordinated and efficient harvesting and marketing.

The former effect would probably encourage integration and the latter encourage non-integration of forest ownership. The overall impact would depend on the balance of these two effects.

Forest owner associations are widespread in Sweden and often help their members harvest and sell their logs. The only association of forest owners in New Zealand is the Farm Forestry Association, which mainly offers members a forum to meet likeminded farmers and exchange ideas. It does not have a role in coordinating harvesting and sales, although it can facilitate sawmill and pulpmill's contacts with small forest owners and improve forest owners' market savvy.

4.3.2 Site specificity

Site specificity is the degree to which a production unit is dependent on the supply available at its particular location. An important concept in considering site specificity is the mill's fibre basin. As discussed, a radius of 120 km was assumed in this study.

The survey measured site specificity in terms of the volume of fibre available in the fibre basin relative to mill needs. If the mill's needs represent a higher proportion of the supply in the basin, the mill is more dependent on that fibre basin and should have greater incentive to integrate.

Another important factor determining site specificity and a mill's sense of supply security is the fibre balance in the basin. For example, a supply surplus and net export of logs will increase a mill's supply security, because the cost of exporting logs from the fibre basin will almost always be greater than delivery to the local market. Suppliers will therefore normally prefer to sell to a local consumer than to export. Similarly, imported logs will normally be more expensive and less attractive to buyers than local log supplies, and a net fibre deficit (import) will usually make sourcing fibre on the local market more difficult.

One way that mills can influence their site specificity is to engage in “fibre swaps” with other mills. For example, if the mill owner had access to fibre in another basin (from own forests, chips or through contracts), and a mill owner in that basin in turn had access to fibre in the first basin, then the two could swap fibre to their mutual advantage. This is a quite common practice in the Swedish forest industry, in order to reduce transport costs and increase security of supply.

4.3.3 Technical specificity

Technical specificity is the level to which the production unit’s equipment and processes are tailored to a specific supply. The level of technical specificity in both the sawmill and pulp industry is very high, with mills’ operations and marketing being highly interrelated with the type of fibre used. This resource-specific investment would be expected to increase a mill’s incentive to integrate.

It was however not practical to probe sawmills on the log grade used. There is no standard log grade system in either NZ or Sweden (forest owners tend to have different systems), and the systems that exist are very complex. While there are usually only a few pulpwood grades, there is enormous variation in sawlog grades. Sawlogs are usually graded by diameter and length, and even by knot size in NZ. The limits for the dimensions vary, and the various combinations can yield 20-40 grades. Pulpwood grades are often simply species-related, because it is fibre qualities not log dimensions that are of most importance for pulp manufacture.

For these reasons, it was decided to measure technical specificity in terms of the species used, and participants’ own rating of how specific the fibre consumed at their mill is to their particular operations (in terms of dimensions, wood qualities, etc). Mills using "minority" species have higher specificity, while using common species or a mix of several species have lower specificity.

In NZ, the majority of sawmills use radiata pine, but some use Douglas fir, and a few use *Eucalyptus* species. Swedish sawmills are mostly focused on either pine (often for appearance-grade applications) or spruce (often for structural applications). Pulpmills tend to mix species to a higher degree, because they often have several pulp lines, and because integrated pulp-paper mills usually want both hardwood and softwood fibre in the paper. In Sweden the main pulpwood species are spruce, pine and birch, while in NZ they are radiata pine and *Eucalyptus* species.

4.3.4 Human capital specificity

Human capital specificity is the degree to which the skills, experience, and other qualities of the organisation’s employees are suited specifically to the input supply. In general, human capital investment is a relatively small part of a forest owner or a mill owner's total capital investment, and unlikely to influence their integration decisions.

Forest owners are unlikely to invest in mill-specific human capital with regard to silviculture (forest tending), given the long lead times required before harvest and thereby large uncertainty about who the best customer will be. In the forest-to-mill supply chain, the mill-specific investment is focused on harvesting operations. However, when these are highly specific to a given mill’s operations, a mill could secure these investments simply by acquiring its own harvesting operations, without actually needing to own forestland.

Mills that are geared towards a certain type of resource (i.e. have high technical specificity) will likely invest in resource-specific human capital in order to run their operations most effectively. This would indeed mean higher costs of losing access to that resource, and may encourage integration into forest ownership. It may also be seen in the extent to which procurement staff build relationships with forest owners. This effect is very much related to technical specificity, and should be captured by the survey in the participants’ rating of fibre specificity.

5 RESULTS

From the survey and complementary data, 22 variables were defined. Of these, three could be used as dependent variables, two are measures of transaction frequency, four relate to uncertainty, nine are measures of asset specificity, and the remaining four are the non-TCE factors tested. The following section provides a summary of that data, and the regression models derived to help understand the factors influencing integration.

5.1 Summary of data

An initial scan of the results reveals that integrated mills are relatively few; only 33 of the 88 participant mills used logs or chips from own sources, and full integration was 13.7% on average (refer to Table 2). Forest ownership is even more rare; the number of mills using logs from own forests was 29, and own logs represented on average only 11.0% of consumption. Partial integration through long-term supply contracts is more common; 57 of the mills used some contract fibre.

The main source of fibre is the open market, representing 49.5% of consumption on average. Of the 88 mills, 75 used some market fibre, and 22 sourced all fibre from the market. The distribution of the fibre mix variable is summarized in Figure 2.

This means that when modelling the drivers of integration, it would be difficult to get significant results by looking at the share of wood from own forests. It is therefore necessary to study integration in terms of fibre both from own forests and from long-term contracts, versus the open market.

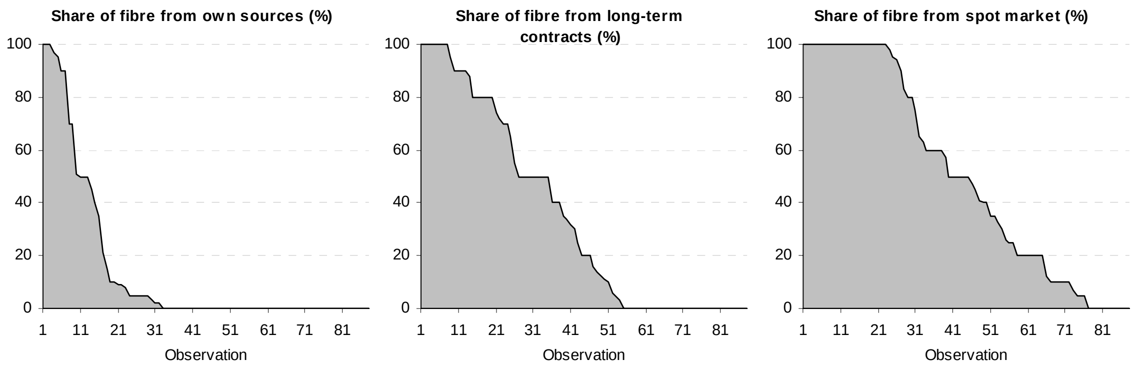
Average mill size was around 225,000 dry tonnes per year of wood consumption[9], but this varies greatly by milltype; for sawmills the average was 90,000 dry tonnes, while

[9] Assuming dry density of 500kg/cubic meter for sawmills, which reported consumption in cubic meters

for pulpmills it was 513,000 tonnes (refer to Appendix 2 for a data summary by milltype). The number of mills owned by the same organisation in the same fibre basin was two on average, with a maximum of 13 in the case of one sawmill in Southern Sweden. This reflects the density of the industry that part of Sweden, the size of some of the forest product companies, and their asset concentration in certain regions.

Figure 2: Distribution of fibre mix

The following graphs show the 88 observations ordered by the share of their fibre consumption obtained from each source (internally, through long-term contracts, and the open market) respectively.



It seems that respondents are more concerned about price volatility than they are about the costs of price discovery. This helps explain why sourcing from the market is relatively popular; price volatility makes contracting more difficult, while price transparency enables fairer market transactions.

Unsurprisingly, market concentration was reported higher for buyers than both forest ownership and chip supply. Forest ownership tends to be more fragmented than the wood processing industry. This was especially apparent in Sweden, and may explain why mills in Sweden report less supply uncertainty that those in New Zealand (refer to Appendix 2 for a data summary by region). However, the New Zealand mills enjoy a better fibre trade balance, as will be discussed further in section 5.3.

On average, forest owner associations are perceived to have an upward influence on fibre prices. But again, there is significant regional variation; the Swedish respondents rated the impact of associations much higher than those in New Zealand. Similarly, few mills reported any significant degree of fibre swaps, but it appears much more common in Sweden.

Table 2: List of variables defined from data

Variable category	Variable	Description	Mean	Std. dev.	Min-imum	Max-imum
Dependent variable(s)	*fibreo*	Share of fibre consumption that is from own forests or mills, %	13.7	26.6	0	100
	fibrec	Share of fibre consumption that is from long-term contracts, %	36.8	36.8	0	100
	fibrem	Share of fibre consumption that is from the open market, %	49.5	38.5	0	100
Transaction frequency	*size*	Mill fibre consumption, in thousand metric tonnes	224.5	279.2	0	1250
	mills	Number of mills (in the fibre basin) owned by the organisation	2.2	2.1	1	13
Uncertainty	*uncert*	Uncertainty of supply (Likert scale, 1=very reliable → 5=highly uncertain)	2.9	1.4	1	5
	pricevol	Price volatility (Likert scale, 1=very stable → 5=highly volatile)	2.9	1.0	1	5
	costcon	Costs of monitoring and enforcing contracts (Likert scale, 1=not significant → 5=very significant)	2.4	1.2	1	5
	costprice	Difficulty of monitoring market price for fibre (Likert scale, 1=simple/easy, 5=very difficult)	1.8	0.8	1	4
Asset specificity	*forcon*	Forest owner concentration; share of largest three owners in fibre basin (1=0-10%, 2=11-20%, 3=31-40, 4=41-60%, 5= >60%)	3.4	1.4	1	5
	chipcon	(Relates to pulpmills only). Chip supplier concentration; share of largest three suppliers in fibre basin (1=0-10%, 2=11-20%, 3=31-40%, 4=41-60%, 5=>60%)	3.5	1.1	1	5
	buycon	Buyer concentration; share of largest three consumers of fibre in the fibre basin (1=0-10%, 2=11-20%, 3=31-40%, 4=41-60%, 5= >60%)	4.3	0.9	1	5
	sitesp	Site specificity; fibre supply in the fibre basin relative to mill's needs (1= >10x, 2= 7-10x, 3= 5-6x, 4= 3-4x, 5= 1-2x needs)	3.0	1.6	1	5
	balance	Fibre balance in basin (1=export >10%, 2=export 0-10%, 3=balance, 4=import 0-10%, 5=import >10%)	2.9	1.5	1	5
	fibresp	Degree to which the fibre consumed is specific to the mill's particular operations (Likert scale, 1=not at all specific → 5=highly specific)	3.3	1.4	1	5
	sp_type	Type of species consumed (1=common, 2=mixed, 3=niche)	1.3	0.5	1	3
	sp_number	The number of different species consumed	1.6	0.8	1	4
	grade	Main grade produced at the mill, for saw/pulpmills: 1= >60% structural lumber /mechanical pulp, 2= 40-60% of each, 3= >60% appearance lumber /chemical pulp	1.8	0.9	1	3
Non-TCE factors	*assoc*	Perceived impact of forest owner associations on fibre costs, (1=lower costs, 2=no impact, 3=higher costs)	2.4	0.7	1	3
	formown	Form of mill ownership (1=private, single mill, 2= private, multi-mill, 3=public, single mill, 4= public, multi-mill)	2.2	1.2	1	4
	millage	Age of the mill; year of first establishment	1940.4	40.2	1765	2001
	swaps	Degree to which the mill engages in strategic fibre swaps (1=no, 2= yes to limited degree, 3= yes to significant degree)	1.4	0.7	1	3

5.2 Combined model

The dependent variable chosen for the modelling was *fibrem*, the proportion of fibre from the open market. Before modelling the combined data, correlations were studied in order to test for collinearity in the explanatory variables (refer to Table 3). No variable combinations had scores of >0.7, which would raise concern. Those combinations with a relatively high correlation include *sp_number*/*sp_type* and *sp_number*/*grade*; these three variables were all intended to measure mills' technical specificity.

Not surprisingly, *size* is positively correlated with *sitesp (*mill demand relative to total supply*)*, *sp_number* (the number of species consumed) and *formown (*form of ownership, where public has a higher score than private, and multiple-mills higher than single-mill organisations*)*. It is also interesting that *forcon* (forest owner concentration) is quite highly and positively correlated with *uncert* (perceived uncertainty of supply)[10]. The dependent variable, *fibrem* is mostly highly correlated with the variables *mills*, *uncert*, *costprice*, *balance*, *fibresp*, *formown*, *millage* and *swaps*, and this gives some early clues about what factors might be important for the integration decision.

Table 3: Correlation matrix of all variables

Scores that are > 0.7 or <-0.7 are shown in bold text.

	fibrem	size	mills	uncert	price-vol	cost-con	cost-price	forcon	buy-con	sitesp	bal-ance	fibre-sp	sp_type	sp_number	grade	assoc	form-own	mill-age	swaps
fibrem	**1.00**																		
size	-0.10	**1.00**																	
mills	-0.23	0.23	**1.00**																
uncert	-0.29	0.00	-0.01	**1.00**															
pricevol	0.08	-0.09	0.01	0.09	**1.00**														
costcon	-0.08	-0.12	-0.09	0.06	0.11	**1.00**													
costprice	-0.21	-0.16	0.08	0.27	0.24	0.21	**1.00**												
forcon	-0.13	-0.23	-0.05	0.34	0.07	0.20	0.06	**1.00**											
buycon	0.01	0.06	0.08	0.04	0.16	-0.17	-0.16	0.11	**1.00**										
sitesp	0.01	0.48	0.18	0.10	-0.02	-0.30	-0.03	-0.19	0.16	**1.00**									
balance	-0.21	0.32	0.19	0.18	0.11	-0.10	0.00	-0.04	0.28	0.11	**1.00**								
fibresp	-0.36	-0.18	0.05	0.20	0.07	0.31	0.33	0.35	-0.12	-0.21	-0.03	**1.00**							
sp_type	-0.02	0.21	-0.10	0.02	0.01	-0.06	-0.08	0.10	0.23	0.23	0.11	-0.09	**1.00**						
sp_number	-0.01	0.50	-0.05	-0.12	0.08	0.07	-0.01	-0.21	0.12	0.21	0.30	-0.20	0.51	**1.00**					
grade	-0.02	0.40	0.01	0.09	0.08	0.01	0.11	-0.18	0.00	0.21	0.08	0.03	0.14	0.38	**1.00**				
assoc	0.03	0.18	0.24	0.01	0.05	-0.03	0.13	-0.15	-0.06	0.13	0.08	-0.20	0.06	0.18	0.10	**1.00**			
formown	-0.22	0.52	0.26	-0.08	-0.24	-0.24	-0.05	-0.39	0.02	0.32	0.17	-0.10	0.03	0.14	0.14	0.23	**1.00**		
millage	0.32	-0.20	-0.22	-0.05	-0.06	0.00	-0.17	0.17	-0.03	-0.09	-0.17	-0.07	0.02	-0.15	-0.07	-0.29	-0.31	**1.00**	
swaps	-0.36	0.25	0.27	0.09	-0.15	-0.07	0.09	0.06	-0.07	0.13	0.04	0.17	-0.01	0.01	-0.03	0.03	0.37	-0.22	**1.00**

[10] This was particularly evident among pulpmills, where the correlation was 0.61

As discussed in section 3.3, fractional logit regression was chosen as the most appropriate model (tobit and ordinary least squares regression were also tested, and these are presented in Appendix 3).

Initially, a model with all variables was constructed to identify which TCE factors seem most relevant. This model is shown in Table 4. Two dummy variables were used, one to control for milltype (sawmills=0, pulpmills=1), and the other for region (Sweden=0, New Zealand=1). Many variables have very low significance, and should clearly be dropped from the model immediately. These included two TCE factors relating to uncertainty (*costcon* and *costprice)* and five relating to asset specificity (*buycon, sitesp, grade*, *sp_type* and *sp_number)*.

Table 4: Combined fractional logit model, all factors

Variable category	Variable	Coefficient	Standard error	Z	P>|z|
Dummy variables	milltype	-1.34	0.57	-2.37	0.02
	region	0.83	0.73	1.13	0.26
Transaction frequency	size	0.00	0.00	1.66	0.10
	mills	-0.14	0.08	-1.76	0.08
Uncertainty	uncert	-0.29	0.15	-1.92	0.05
	pricevol	0.28	0.23	1.21	0.23
	costcon	-0.08	0.19	-0.44	0.66
	costprice	-0.16	0.31	-0.52	0.60
Asset specificity	forcon	-0.19	0.20	-0.94	0.35
	buycon	0.07	0.24	0.31	0.76
	sitesp	-0.01	0.14	-0.04	0.97
	balance	-0.17	0.12	-1.38	0.17
	fibresp	-0.39	0.17	-2.31	0.02
	sp_type	-0.26	0.47	-0.56	0.58
	sp_number	0.11	0.36	0.32	0.75
	grade	-0.01	0.25	-0.05	0.96
Non-TCE factors	assoc	0.30	0.26	1.17	0.24
	formown	-0.02	0.21	-0.08	0.94
	millage	0.01	0.01	1.15	0.25
	swaps	-0.49	0.29	-1.70	0.09
-	(constant)	-14.19	15.33	-0.93	0.36

Costcon relates specifically to contracts, but could have opposite impacts on *fibrem*[11]. *Costprice* (the difficulty of price discovery) was expected to be positively associated with integration. Its coefficient has the expected sign, but no significance.

TCE theory holds that high market concentration of buyers (*buycon*) can cause market failure, and thereby encourage integration. However, it could also indicate that a few mills hold a strong bargaining position relative to forest owners, and thereby less incentive to integrate. *Sitesp*, a mill's fibre consumption relative to total supply in the basin, was expected to be positively associated with integration. A theory in TCE research is that firms consuming a small share of total demand for an input are less likely to integrate, since they would lost the risk-pooling economies of large markets, but the results are mixed (Lieberman, 1991). In any case, it is not a true measure of site specificity, which is the degree to which a firm is dependent on a source of supply due to its proximity, and indeed all mills have supply basins constrained by fibre transport economics. *Grade, sp_ type* and *sp_number*, are all related to mills' technical specificity, but were not found significant.

The variable *uncert* (perceived uncertainty of supply) was also dropped due to its relatively high and positive correlation with *forcon* (forest owner concentration). Two very similar final models could be derived, one using the variable *uncert* and the other with *forcon*. The model using *forcon* was preferred, because it seems most likely that forest owner concentration leads to increased supply uncertainty, and that in turn increases the incentive for mills to backwards integrate.

The variable *swaps* was dropped because it seems most likely that integration influences mills' propensity to engage in strategic fibre swaps, rather than the reverse. *Swaps* was found significantly associated with integration, but not with the expected sign. It was originally hypothesized that swapping fibre with other forest owners could increase supply security without requiring forest ownership in the mill's fibre basin, but it appears that mills that engage more heavily in swaps are more likely to source fibre

[11] High costs of monitoring and enforcing contracts could encourage either full integration (forest ownership) or full use of the open market

from own forests. This may be because the motivation to swap fibre is primarily transport-cost driven, and only integrated forest products companies can swap fibre. Removing these variables, and non-significant variables in successive models, the final model was derived (refer to Table 5). In this process, a further five variables were dropped due to non-significance: one relating to uncertainty (*pricevol*), one measure of asset specificity (*balance*), and three non-TCE factors (*assoc*, *formown*, *millage*).

Table 5: Combined fractional logit model

Variable category	Variable	Coefficient	Standard error	Z	P>|z|
Dummy variables	milltype	-1.531	0.508	-3.01	0.00
	region	1.295	0.447	2.90	0.00
Transaction frequency	size	0.001	0.001	1.99	0.05
	mills	-0.140	0.067	-2.09	0.04
Asset specificity	forcon	-0.377	0.164	-2.30	0.02
	fibresp	-0.525	0.149	-3.53	0.00
-	(constant)	2.996	0.751	3.99	0.00

There is strong support for TCE theory with respect to some variables, including:

- *mills*, the total number of mills the owner has in the fibre basin, an indicator of transaction frequency and site specificity. As expected, a greater number of mills corresponds to more integration.
- *forcon*, the concentration of forest ownership, a measure of asset specificity and often closely linked to market failure. As expected, higher concentration is associated with more integration.
- *fibresp*, the degree to which the fibre that the mill consumes is specific to the mill's operations, a measure of asset specificity. As expected, higher specificity seems to encourage more integration.

Mills' annual fibre consumption, an indicator of transaction frequency, should be an important integration factor according to TCE theory. While *size* was found to have strong predictive power, its influence was not in the expected direction; larger mills seem to source more of their fibre from the market (as long as the dummy *milltype* variable controls for differences between sawmills and pulpmills). This is a surprising result, and difficult to explain. The coefficient is however close to zero; when the *milltype* dummy is removed, it assumes the expected sign and loses significance.

The negative coefficient of the milltype dummy indicates that *ceterus paribus*, pulpmills tend to source less of their fibre needs on the open market. This is not surprising, given pulpmills' higher capital costs and fibre consumption. A pulpmill can cost between USD 250 million and USD 1 billion. In contrast, a large and modern sawmill would typically not cost more than USD 100 million. This means that pulpmills have higher semi-appropriable quasi rents, and thereby greater incentive to integrate and thereby ensure supply security.

Pulpmills also have much higher fibre consumption on average, reflected in the survey data in Table 2. If the economic sourcing radius is the same as for sawmills (if anything it should be smaller, given lower value of pulpwood relative to sawlogs), then pulpmills will tend to have more difficulty sourcing their fibre needs in the supply basin.

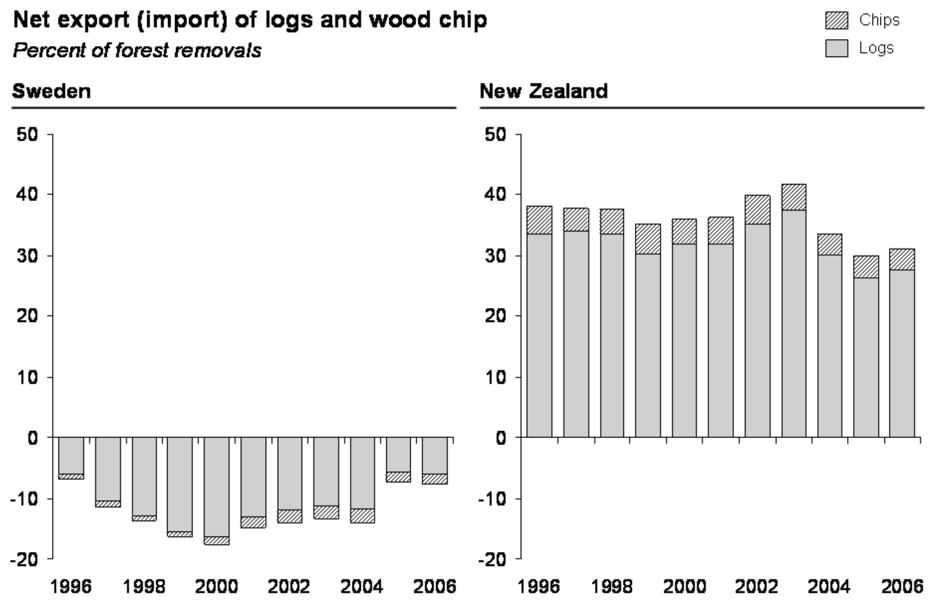
Furthermore, the positive coefficient on the region dummy indicates that *ceterus paribus*, mills in New Zealand tend to source more of their fibre needs from the open market than mills in Sweden. Again, this result is not surprising, given fundamental differences in the two fibre markets. This is explored further in the following section.

5.3 Regional models

There are some differences between the fibre markets of New Zealand and Sweden that could be expected to drive differences in forest-mill integration patterns. One thing they have in common is a mixed and fragmented forest ownership (refer to Figure 1). Sweden has a somewhat higher state forest ownership than New Zealand (due to the Swedish government's stake in Sveaskog). But apart from that, the relative share of companies and small forest owners, and the overall concentration of forest ownership, are very similar.

Two key differences between Sweden and New Zealand are the fibre trade balance and predominance of sawmills versus pulpmills. Sweden is a net importer of logs and chips, in the order of 10-20% of domestic production. In contrast, New Zealand exports 30-40% of log and chip production (refer to Figure 3). Wood processors in New Zealand can be relatively confident of obtaining fibre at competitive prices, since forest owners' alternative is to export to very distant markets (predominantly Eastern Asia).

Figure 3: Fibre balance in Sweden and New Zealand



Source: NZ Ministry of Forestry, "Trade and Production Statistics", 2007; Statistics New Zealand, "Forestry Flow Tables 1996-2003", 2005; Swedish Forest Agency "Yearbook of Forestry", 2007; FAO, "FAOSTAT", 2007

The pulp and paper industry is relatively underdeveloped in New Zealand, where there are at least 25 sawmills for every pulpmill. In Sweden the ratio is around 5 (refer to Table 1). In terms of fibre consumption, New Zealand sawmills consume around 8 million cubic metres of sawlogs, while the pulpmills consume only 5 million cubic metres of pulplogs and chips[12]. In Sweden the relative consumption is the reverse, at around 35 and 45 million cubic metres respectively.

[12] Based on production data from FAO, and assuming 50% lumber conversion, 45% chemical pulp conversion, 80% mechanical pulp conversion, and a wood density of 0.5 dry tonnes per cubic meter

Another difference is that forest growth rates are much higher in New Zealand. Radiata pine plantations typically yield around 20 m^3/ha/year, whereas the net annual increment of Swedish forests is only 5 m^3/ha/year. A given supply radius in New Zealand can potentially support more processing capacity than the same radius in Sweden. The wood products industry in New Zealand does tend to be concentrated in clusters, whereas it is relatively evenly distributed throughout Sweden. A large pulpmill in New Zealand could support itself completely with forestlands very near the mill.

These regional differences could be expected to cause differences in forest-mill integration patterns. Indeed, the survey results indicate that integration is significantly higher in Sweden than New Zealand (refer to Table 6). Swedish mills have a greater reliance on own sources and long-term contracts, and less on open market supply. A full summary of data by region is provided in Appendix 1.

Table 6: Supply integration in Sweden and New Zealand

Fibre source	**Description**	***Sweden***		***New Zealand***		**Two tail t-test, P(|T|<|t|)**
		Average	**Std. dev.**	**Average**	**Std. dev.**	
fibreo	Share of fibre consumption that is from own forests or mills, %	14.1	26.0	12.8	28.0	0.83
fibrec	Share of fibre consumption that is from long-term contracts, %	41.7	35.8	28.8	37.5	0.11
fibrem	Share of fibre consumption that is from the open market, %	44.2	36.4	58.4	40.9	0.09

Whereas the combined model presented in chapter 5.2 was derived by first testing all variables then successively removing those that are least significant, a slightly different process was required for the strata due to their more limited number of observations. Full-variable models for the strata were often not statistically meaningful. A rule of thumb suggested by Long (1997) is that for every explanatory variable included in a logit model, there should be 10 observations. For example, a model for New Zealand mills, with a sample size of 33, should have no more than three explanatory variables. The approach employed was therefore to test various models, focusing on those explanatory variables found most relevant in the combined model. The models presented in Table 7 are those that had the highest likelihood scores. Note that there was no significant colinearity among any of the variables in the regional strata.

The models derived for the two regions are actually very similar, including the same explanatory variables and with the same sign on the coefficients:

- *milltype*: pulpmills are more likely to be integrated than sawmills.
- *forcon*: high concentration of forest ownership encourages integration.
- *fibresp*: the more specific the fibre is to the operation, the more integration.

The coefficients of the explanatory variables are larger for New Zealand, suggesting that integration in New Zealand is more sensitive to these factors than in Sweden. The constant also has a higher value for New Zealand, indicating that these three variables do not fully explain why the share of fibre sourced from the open market is higher in New Zealand than in Sweden.

Table 7: Regional fractional logit models

Variable category	Variable	*Sweden*		*New Zealand*	
		Coefficient	**P>|z|**	**Coefficient**	**P>|z|**
Dummy variable	milltype	-0.68	0.09	-1.78	0.02
Asset specificity	forcon	-0.31	0.06	-0.92	0.08
	fibresp	-0.44	0.01	-0.77	0.01
-	(constant)	2.23	0.00	7.68	0.00

It is also interesting to note the explanatory variables that were significant in alternative models tested (refer to Appendix 3). For both regions, there is evidence that greater supply uncertainty (*uncert*) encourages integration. Another variable that may be relevant in Sweden is s*p_type*; where the use of less common species is associated with integration. Finally, the variable *balance* (local fibre balance) frequently featured in models for New Zealand with a significant negative coefficient, suggesting that mills operating in areas with a fibre shortage are more likely to have integrated supply.

5.4 Pulpmill and sawmill models

As discussed, there are regional factors which impact the integration decision differently in Sweden and New Zealand. In the same way, there are fundamental differences between sawmills and pulpmills which could be expected to impact the integration decision significantly. Two of the most important differences are:

1. Fixed costs - Pulpmills tend to be much more expensive to build or buy than sawmills, and therefore have higher semi-appropriable quasi rents.
2. Scale - Pulpmills have much higher fibre consumption on average, which could mean that have greater difficulty obtaining sufficient fibre.

Given these differences, and according to TCE theory, one would expect pulpmills to have greater incentive to integrate than sawmills. The pulpmills surveyed did indeed source a significantly lower share of supply from the open market than sawmills (refer to Table 8). And the significance of the *milltype* dummy variable in the combined model indicated that pulpmills' greater propensity to integrate cannot be explained by those explanatory variables only (*size*, *mills*, *forcon* and *fibresp*).

Table 8: Supply integration in sawmills and pulpmills

Fibre source	**Description**	***Sawmills*** Average	***Sawmills*** Std. dev.	***Pulpmills*** Average	***Pulpmills*** Std. dev.	**Two tail t-test, P(|T|<|t|)**
fibreo	Share of fibre consumption that is from own forests or mills, %	12.0	25.1	17.1	29.8	0.40
fibrec	Share of fibre consumption that is from long-term contracts, %	33.2	35.7	44.7	38.4	0.17
fibrem	Share of fibre consumption that is from the open market, %	54.8	39.4	38.1	34.6	0.06

Several alternative models were tested, the two milltype-specific fractional logit models were derived (refer to Table 9). With only 28 observations for pulpmills, that model is necessarily small. For pulpmills, higher integration was found positively associated with forest owner concentration and fibre specificity. This is the same result as for the combined model and consistent with TCE theory.

For sawmills, integration was positively associated with mill size, the number of mills in the fibre basin, and the cost of price discovery. Again, this is consistent with TCE theory. Interestingly, forest owner concentration was not found significant for sawmills, and price volatility would appear to discourage integration. While supply uncertainty is generally expected to drive integration, Lieberman (1991) suggests that volatility in an input market may discourage integration if the volatility of the input and product markets are correlated. Given the significance of fibre for pulpmill and especially sawmill operating costs, and the competitive nature of these industries, it is not surprising that product prices tend to follow fibre prices. Therefore, non-integration may be attractive from a risk management perspective.

Table 9: Sawmill and pulpmill fractional logit models

		Sawmills		***Pulpmills***	
Variable category	***Variable***	**Coefficient**	**P>|z|**	**Coefficient**	**P>|z|**
Transaction frequency	size	-0.005	0.06		
	mills	-0.153	0.04		
Uncertainty	pricevol	0.516	0.01		
	costprice	-0.632	0.06		
Asset specificity	forcon			-0.42	0.01
	fibresp	-0.382	0.05	-0.50	0.00
-	(constant)	2.23	0.07	2.10	0.00

6 DISCUSSION AND CONCLUSIONS

Support for TCE theory in fibre-supply integration

The results lend support for the significance of TCE factors in fibre-supply integration. There is evidence that variables within all three categories of TCE factors (frequency, asset specificity, and uncertainty) impact forest-mill integration decisions, but foremost asset specificity (refer to Table 10).

Integration is clearly more likely if the organisation owning the mill also owns several other mills in the fibre basin. The role of mill size remains unclear. As a proxy for transaction frequency, large mills were expected to be integrated to a greater extent. However, mill size was found to be negatively associated with integration in the combined model (while milltype was controlled for), and negatively associated with integration for sawmills.

Table 10: Summary of findings

TCE factor categories	Evidence for factor's importance	Variables found to have significance	Impact on integration		
			Expected	Actual	Notes
Frequency	Fair	• Number of mills in basin (*mills*)	+	+	
		• Mill size (mills)	+	-	(1)
Uncertainty	Weak	• Uncertainty of fibre supply (*uncert*)	+	+	(2)
		• Cost of price discovery (costprice)	+	+	
		• Price volatility	+/-	-	(3)
Asset specificity	Strong	• Fibre specificity (*fibresp*)	+	+	
		• Forest-owner concentration (*forcon*)	+	+	
Non-TCE factors	Strong	• Mill type (*milltype*)	N/A		(4)
		• Region (*region*)	N/A		(4)

Notes: (1) Mill size was found negatively associated with integration in the combined model (while the milltype dummy present), but positively associated with integration in the sawmill model. (2) *Uncert* was found positively and significantly associated with integration, but highly correlated with *forcon*; it seems most likely that concentrated forest ownership leads to both supply uncertainty and supply integration. (3) TCE theory predicts high volatility in the input market to encourage supply integration, unless correlated with volatility in the product market. (4) Integration was found to be higher for pulpmills than for sawmills, and higher in Sweden than in New Zealand.

There was relatively weak evidence for the importance of supply uncertainty in driving integration. Integration was found positively associated with mill staffs' ratings of supply uncertainty, but the variable *uncert* lost significance when *forcon* was included in the model. The two variables were positively correlated, and it seems likely that forest owner concentration is driving both supply uncertainty and integration. Another two uncertainty factors were found significant for sawmills only; *costprice* and *pricevol*. As expected, the cost of price discovery seems to encourage integration. More surprisingly, price volatility seems to discourage integration. This may be because product prices follow fibre prices and integration (at least in the form of long-term contracts) could be a relatively risky option in volatile markets.

The most important drivers of integration seem to be those relating to asset specificity. These are factors that lead to less competitive markets for a mill's fibre needs, increased risk for hold-up, and thereby greater incentive to integrate. Fibre specificity, the degree to which a mill's fibre needs are specific to its particular operations, was found positively and significantly associated with integration in almost all models tested. Similarly, forest owner concentration seems to encourage integration, although this factor was not found significant in the sawmill model.

Pulpmills were found more likely to be integrated than sawmills, and this is probably due mainly to asset specificity factors; they tend to have much larger scale (and are thereby more dependent on the entire supply basin, as defined by transport economics), and require much higher capital costs (which increases the risk and cost of hold-up). Forest-mill integration also seems to vary by region, whereby mills in Sweden have a significantly higher level of integration than those in New Zealand. A very similar set of factors seems to influence the integration decision in both regions, but those factors do not fully explain why integration is higher in Sweden. One explanation is that non-TCE factors may also influence the integration decision.

The importance of non-TCE factors

There are indications that non-TCE factors play an important role in fibre-supply integration. The differences in New Zealand and Sweden could not be fully explained by the variables measured; either an important TCE-related factor is missing or poorly measured, or non-TCE factors are responsible (such as the historical development of the respective industrial cultures). Non-TCE factors can present the most important considerations for the integration decision. In the United States for example, taxation laws favour the REIT[13] organisational structure over corporate ownership of timberlands, which has encouraged integrated pulp and paper companies to sell or separate the ownership of their timberlands. This can even impact forest ownership patterns internationally; the American company Rayonier Inc holds timberlands in New Zealand, which are included in their "taxable REIT subsidiary" formed in 2003. Rayonier divested their wood processing assets in New Zealand in 2005, with the sale of the medium density fibreboard mill in Matura.

Furthermore, both the interviews prior to conducting the survey and the survey results indicate a range of non-TCE factors are often taken into consideration. The last question in the survey was "*What other factors influence your organisation's decision on whether to own forest to supply the mill?*" The three most common considerations were: capital intensity; focus on core business/competencies; risks of forest ownership. Over 90% of responses for pulpmills, and around 70% for sawmills, were in these three categories. The fourth most common consideration was "soft" factors, such as an organisation's identity and affinity to forest assets. This was almost exclusively observed among sawmill respondents, who often also cited considerations of taxation and availability of forestland to purchase. In general, it appears that the barriers to forest ownership are considered more formidable for sawmill owners, while pulp manufacturers are to a greater extent concerned about focusing on their core business.

Research limitations and areas for further research

This is the first study of its kind, with a relatively small sample size and coverage of only two regions. Further research is required to gain a clear understanding of TCE's role in fibre-supply integration, and forest ownership in particular.

A limitation of using survey data is that it relies on the accuracy and consistency of the participants' responses. The answers given must depend to some degree on the

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[13] Real-Estate Investment Trust, a tax designation for a corporation investing in real estate that reduces corporate income tax, but requires that at least 75% of assets are real-estate, cash or government securities

individual participant; they are for example subject to their knowledge and perceptions. The accuracy of the objective measures can be quite well-assured, by cross-checking against the public information available and by applying some common sense. If the responses to the more subjective questions reflect the organisation's perception, they will be useful in explaining that organisation's integration decisions. However, they will be influenced by the individual's perceptions too. An attempt was made to minimize these issues through clear question formulation, good survey design, and prior communication with all participants.

Another limitation of this research is the sample size. The quasi-maximum likelihood estimation method is best suited to a greater number of observations than this research is based on. However, other TCE studies have a similar sample size (Hobbs, 1997, Wang and van Kooten, 1998), and a larger sample was beyond the scope of this study. The survey process can be very time-consuming (for this research, it took more than six months). All participants were contacted personally prior to sending the survey, in order to better inform them of the research objectives and process, increase response rates, and due to potential negative reactions from mass-distribution of unsolicited email. A large and simultaneous distribution of the survey would significantly reduce the time required to collect data. Future research could expand the dataset by surveying the remaining mills in New Zealand and Sweden, or extending the survey to forest industries in other regions, such as Finland, Canada and the United States.

A question that this research raises but does not answer is why the intermediate form of integration (long-term contracts) is so common, and why it may be used instead of either extreme (forest ownership, or full reliance on the market). By offering a level of supply security, while demanding a certain level of commitment, contracts can be considered a form of integration. In the analysis presented here, integration was defined as the proportion of fibre not coming from the market, because forest ownership was found so rare and because long-term contracts appear to be the preferred approach to reduce reliance on the market. Future research could explore why contracts are so popular for mill fibre supply. It may well be due to pre-existing factors, such as the barriers to acquisition of forestland in Sweden, and the legacy of forestland divestments by integrated forest product companies in New Zealand.

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9 APPENDICES

Appendix 1: Data summary tables

Data summary by region

Variable category	Variable	Mean		Std. dev.		Minimum		Maximum	
		Swe.	*NZ*	*Swe.*	*NZ*	*Swe.*	*NZ*	*Swe.*	*NZ*
Independent variable(s)	fibreo	14.1	12.8	26.0	28.0	0	0	100	95
	fibrec	41.7	28.8	35.8	37.5	0	0	100	100
	fibrem	44.2	58.4	36.4	40.9	0	0	100	100
Transaction frequency	size	292.2	111.7	299.3	199.4	18	0	1250	990
	mills	2.6	1.6	2.3	1.4	1	1	13	6
Uncertainty	uncert	2.8	3.2	1.4	1.4	1	1	5	5
	pricevol	3.0	2.8	1.0	1.2	1	1	5	5
	costcon	2.2	2.6	1.1	1.3	1	1	5	5
	costprice	1.8	1.6	0.8	0.7	1	1	4	3
Asset specificity	forcon	2.8	4.5	1.4	0.8	1	1	5	5
	chipcon	3.4	4.0	1.2	0.0	1	4	5	4
	buycon	4.3	4.4	0.9	0.9	1	2	5	5
	sitesp	3.1	2.8	1.5	1.7	1	1	5	5
	balance	3.1	2.6	1.4	1.4	1	1	5	5
	fibresp	3.0	3.6	1.4	1.2	1	1	5	5
	sp_type	1.2	1.4	0.4	0.7	1	1	2	3
	sp_number	1.8	1.3	0.8	0.6	1	1	4	3
	grade	1.9	1.8	0.9	0.9	1	1	3	3
Non-TCE factors	assoc	2.5	2.2	0.7	0.6	1	1	3	3
	formown	2.6	1.6	1.3	0.8	1	1	4	4
	millage	1925	1967	40.8	21.3	1765	1906	2000	2001
	swaps	1.5	1.1	0.8	0.3	1	1	3	2

Data summary by milltype

Variable category	Variable	Mean		Std. dev.		Minimum		Maximum	
		Saw	*Pulp*	*Saw*	*Pulp*	*Saw*	*Pulp*	*Saw*	*Pulp*
Independent variable(s)	fibreo	12.0	17.1	25.1	29.8	0	0	95	100
	fibrec	33.2	44.7	35.7	38.4	0	0	100	100
	fibrem	54.8	38.1	39.4	34.6	0	0	100	100
Transaction frequency	size	89.8	513.4	91.9	325.4	0	34	360	1250
	mills	2.1	2.5	2.2	1.9	1	1	13	6
Uncertainty	uncert	3.0	2.9	1.3	1.5	1	1	5	5
	pricevol	3.0	2.8	1.1	1.0	1	1	5	5
	costcon	2.5	2.1	1.2	1.2	1	1	5	5
	costprice	1.9	1.5	0.8	0.7	1	1	4	3
Asset specificity	forcon	3.7	2.9	1.4	1.4	1	1	5	5
	chipcon	n/a	3.5	n/a	1.1	n/a	1	n/a	5
	buycon	4.3	4.5	0.8	1.0	2	1	5	5
	sitesp	2.7	3.6	1.6	1.5	1	1	5	5
	balance	2.7	3.5	1.2	1.7	1	1	5	5
	fibresp	3.4	2.9	1.3	1.5	1	1	5	5
	sp_type	1.2	1.4	0.5	0.5	1	1	3	2
	sp_number	1.4	2.1	0.5	1.1	1	1	2	4
	grade	1.7	2.2	0.8	1.0	1	1	3	3
Non-TCE factors	assoc	2.3	2.6	0.7	0.6	1	1	3	3
	formown	1.7	3.3	0.9	1.0	1	1	4	4
	millage	1948	1925	40.7	34.9	1765	1859	2001	1989
	swaps	1.4	1.5	0.7	0.8	1	1	3	3

Appendix 2: Correlation matrices

Correlation matrix for Swedish mills

Scores that are > 0.7 or <-0.7 are shown in bold text.

	fibrem	size	mills	uncert	price-vol	cost-con	cost-price	forcon	buy-con	sitesp	bal-ance	fibre-sp	sp_type	sp_number	grade	assoc	form-own	mill-age	swaps
fibrem	**1.00**																		
size	0.01	**1.00**																	
mills	-0.16	0.05	**1.00**																
uncert	-0.36	-0.08	-0.04	**1.00**															
pricevol	-0.02	-0.17	-0.02	0.24	**1.00**														
costcon	-0.10	-0.12	-0.24	0.24	0.11	**1.00**													
costprice	-0.26	-0.31	0.06	0.30	0.23	0.38	**1.00**												
forcon	-0.34	-0.08	0.10	0.47	0.20	0.16	0.22	**1.00**											
buycon	0.01	0.06	0.14	-0.01	0.23	-0.29	-0.29	0.07	**1.00**										
sitesp	0.15	0.55	0.16	-0.03	-0.09	-0.27	-0.23	-0.08	0.24	**1.00**									
balance	-0.05	0.22	0.07	0.17	0.32	-0.17	-0.04	0.14	0.27	0.17	**1.00**								
fibresp	-0.42	-0.20	0.07	0.28	0.08	0.30	0.35	0.34	-0.16	-0.27	0.05	**1.00**							
sp_type	-0.12	0.48	-0.14	-0.11	0.09	-0.15	-0.14	-0.14	0.33	0.33	0.18	-0.19	**1.00**						
sp_number	0.12	0.41	-0.28	-0.12	0.08	0.05	-0.08	-0.07	0.19	0.23	0.25	-0.19	**0.75**	**1.00**					
grade	-0.08	0.44	-0.05	0.08	0.05	0.11	0.08	-0.19	-0.03	0.12	0.18	-0.01	0.50	0.46	**1.00**				
assoc	0.03	0.06	0.15	-0.04	-0.15	-0.10	0.05	-0.02	-0.02	0.14	0.01	-0.29	0.12	0.04	-0.03	**1.00**			
formown	-0.15	0.48	0.19	-0.17	-0.37	-0.19	-0.18	-0.25	0.02	0.38	-0.03	-0.04	0.37	0.07	0.21	0.18	**1.00**		
millage	0.34	-0.04	-0.12	-0.20	-0.05	-0.04	-0.11	-0.22	-0.09	0.02	-0.05	-0.27	-0.16	0.05	-0.06	-0.27	-0.18	**1.00**	
swaps	-0.37	0.24	0.28	0.15	-0.27	-0.01	0.06	0.29	-0.04	0.16	-0.03	0.27	0.03	-0.09	0.01	-0.02	0.35	-0.11	**1.00**

Correlation matrix for New Zealand mills

Scores that are > 0.7 or <-0.7 are shown in bold text.

	fibrem	size	mills	uncert	price-vol	cost-con	cost-price	forcon	buy-con	sitesp	bal-ance	fibre-sp	sp_type	sp_number	grade	assoc	form-own	mill-age	swaps
fibrem	**1.00**																		
size	-0.18	**1.00**																	
mills	-0.34	**0.74**	**1.00**																
uncert	-0.26	0.29	0.16	**1.00**															
pricevol	0.25	0.02	0.06	-0.10	**1.00**														
costcon	-0.14	0.04	0.36	-0.23	0.14	**1.00**													
costprice	-0.07	0.11	0.05	0.25	0.26	0.02	**1.00**												
forcon	-0.25	-0.05	0.06	0.00	-0.07	0.02	-0.09	**1.00**											
buycon	-0.02	0.19	0.00	0.09	0.09	-0.04	0.14	0.06	**1.00**										
sitesp	-0.13	0.29	0.17	0.34	0.05	-0.30	0.30	-0.35	0.06	**1.00**									
balance	-0.38	0.42	0.41	0.26	-0.23	0.08	0.00	-0.05	0.38	-0.05	**1.00**								
fibresp	-0.43	0.11	0.20	-0.01	0.07	0.25	0.44	0.02	-0.14	-0.04	-0.07	**1.00**							
sp_type	0.00	0.09	0.04	0.11	-0.03	-0.07	0.05	0.16	0.10	0.22	0.16	-0.12	**1.00**						
sp_number	-0.11	0.61	0.50	-0.03	0.05	0.31	0.05	0.15	0.08	0.08	0.28	0.01	0.56	**1.00**					
grade	0.12	0.32	0.15	0.12	0.11	-0.09	0.14	-0.21	0.06	0.33	-0.13	0.15	-0.17	0.21	**1.00**				
assoc	0.15	0.32	0.38	0.19	0.37	0.21	0.26	-0.03	-0.06	0.04	0.10	0.18	0.12	0.38	0.34	**1.00**			
formown	-0.24	0.41	0.27	0.25	-0.11	-0.18	0.10	-0.03	0.19	0.09	0.47	0.10	-0.23	-0.14	-0.08	0.09	**1.00**		
millage	0.15	-0.19	-0.24	0.14	-0.01	-0.35	-0.19	0.02	-0.11	-0.13	-0.18	-0.05	-0.06	-0.20	-0.02	0.00	0.05	**1.00**	
swaps	-0.29	-0.20	-0.11	0.05	0.12	-0.05	0.06	0.31	-0.11	-0.15	0.05	0.19	0.19	-0.05	-0.34	-0.13	-0.05	0.06	**1.00**

Correlation matrix for sawmills

Scores that are > 0.7 or <-0.7 are shown in bold text.

	fibrem	size	mills	uncert	price-vol	cost-con	cost-price	forcon	buy-con	sitesp	bal-ance	fibre-sp	sp_type	sp_number	grade	assoc	form-own	mill-age	swaps
fibrem	**1.00**																		
size	-0.29	**1.00**																	
mills	-0.32	0.46	**1.00**																
uncert	-0.19	0.05	-0.01	**1.00**															
pricevol	0.16	0.16	0.10	0.02	**1.00**														
costcon	-0.07	-0.23	-0.14	-0.19	0.01	**1.00**													
costprice	-0.33	0.03	0.21	0.22	0.15	0.02	**1.00**												
forcon	-0.06	-0.04	-0.11	0.20	0.03	0.04	-0.12	**1.00**											
buycon	0.09	0.00	-0.01	0.04	0.21	-0.16	-0.06	0.13	**1.00**										
sitesp	-0.04	0.39	0.19	0.22	0.03	-0.32	0.05	-0.01	0.16	**1.00**									
balance	-0.10	0.14	0.14	0.01	0.09	-0.15	-0.01	-0.27	0.12	-0.06	**1.00**								
fibresp	-0.34	0.12	0.11	0.02	0.08	0.17	0.34	0.28	-0.08	-0.02	0.02	**1.00**							
sp_type	0.08	-0.24	-0.20	0.08	-0.09	-0.06	-0.12	0.29	0.12	0.11	-0.03	-0.05	**1.00**						
sp_number	0.06	0.10	-0.19	-0.16	0.01	0.11	0.00	-0.15	-0.20	0.00	0.30	-0.18	0.16	**1.00**					
grade	0.03	-0.04	-0.02	0.14	-0.04	-0.06	0.20	-0.11	-0.04	0.07	-0.15	0.14	-0.19	-0.17	**1.00**				
assoc	0.01	0.11	0.18	0.12	0.07	0.08	0.29	-0.14	-0.25	0.06	0.04	-0.05	-0.06	0.03	0.11	**1.00**			
formown	-0.22	0.33	0.44	0.01	-0.14	0.08	0.27	-0.19	-0.07	0.14	0.02	0.23	-0.21	-0.14	0.13	0.18	**1.00**		
millage	0.28	-0.26	-0.37	-0.07	-0.16	-0.07	-0.32	0.18	0.04	-0.08	-0.29	-0.07	0.17	0.02	0.00	-0.26	-0.30	**1.00**	
swaps	-0.45	0.33	0.37	0.12	-0.19	-0.10	0.19	0.10	-0.07	0.15	0.07	0.16	-0.05	-0.06	-0.17	0.18	0.55	-0.26	**1.00**

Correlation matrix for pulpmills

Scores that are > 0.7 or <-0.7 are shown in bold text.

	fibrem	size	mills	uncert	price-vol	cost-con	cost-price	forcon	buy-con	sitesp	bal-ance	fibre-sp	sp_type	sp_number	grade	assoc	form-own	mill-age	swaps
fibrem	**1.00**																		
size	0.32	**1.00**																	
mills	0.06	0.24	**1.00**																
uncert	-0.56	0.00	0.00	**1.00**															
pricevol	-0.20	-0.08	-0.17	0.24	**1.00**														
costcon	-0.24	0.17	0.05	0.54	0.25	**1.00**													
costprice	-0.10	-0.02	-0.20	0.37	0.40	0.56	**1.00**												
forcon	-0.51	-0.07	0.16	0.61	0.06	0.41	0.27	**1.00**											
buycon	-0.05	-0.12	0.22	0.03	0.14	-0.11	-0.28	0.20	**1.00**										
sitesp	0.33	0.56	0.12	-0.11	-0.01	-0.13	0.01	-0.34	0.04	**1.00**									
balance	-0.29	0.21	0.26	0.45	0.28	0.09	0.20	0.49	0.42	0.18	**1.00**								
fibresp	-0.57	-0.17	-0.02	0.47	-0.04	0.48	0.24	0.38	-0.12	-0.44	0.02	**1.00**							
sp_type	-0.10	0.28	0.07	-0.06	0.36	0.07	0.19	-0.06	0.35	0.32	0.19	-0.03	**1.00**						
sp_number	0.09	0.44	0.02	-0.09	0.31	0.21	0.20	-0.09	0.30	0.25	0.16	-0.11	**0.86**	**1.00**					
grade	0.07	0.50	0.03	0.02	0.42	0.29	0.16	-0.11	-0.06	0.24	0.17	0.02	0.57	**0.72**	**1.00**				
assoc	0.25	-0.03	0.36	-0.23	0.11	-0.17	-0.07	0.02	0.23	0.09	-0.02	-0.41	0.17	0.21	-0.11	**1.00**			
formown	0.05	0.07	-0.07	-0.27	-0.34	-0.64	-0.23	-0.46	-0.15	0.27	-0.06	-0.30	-0.03	-0.17	-0.36	-0.02	**1.00**		
millage	0.32	0.22	0.27	-0.03	0.04	-0.04	-0.04	-0.13	-0.03	0.22	0.28	-0.29	-0.11	-0.14	0.05	-0.18	0.16	**1.00**	
swaps	-0.17	0.29	0.07	0.06	-0.05	0.00	-0.05	0.06	-0.11	0.05	-0.03	0.22	0.02	0.00	0.10	-0.30	0.19	-0.10	**1.00**

Appendix 3: Alternative models

Appendix 3.1: Alternative combined models

Ordinary least squares (OLS) version of combined model

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Dummy variables	milltype	-0.291	0.111	-2.61	0.01
	region	0.253	0.091	2.78	0.01
Transaction frequency	size	0.000	0.000	1.27	0.21
	mills	-0.029	0.018	-1.64	0.11
Asset specificity	forcon	-0.071	0.031	-2.28	0.03
	fibresp	-0.105	0.028	-3.73	0.00
-	(constant)	1.092	0.125	8.76	0.00

Tobit version of combined model

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Dummy variables	milltype	-0.509	0.175	-2.90	0.01
	region	0.482	0.146	3.31	0.00
Transaction frequency	size	0.000	0.000	1.44	0.15
	mills	-0.045	0.028	-1.64	0.11
Asset specificity	forcon	-0.099	0.049	-2.01	0.05
	fibresp	-0.181	0.046	-3.96	0.00
-	(constant)	1.455	0.204	7.13	0.00

Alternative combined fractional logit model, with variable *uncert*

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Dummy variables	milltype	-1.477	0.464	-3.180	0.00
	region	0.605	0.394	1.540	0.12
Transaction frequency	size	0.002	0.001	2.550	0.01
	mills	-0.134	0.072	-1.870	0.06
Uncertainty	uncert	-0.362	0.126	-2.860	0.00
Asset specificity	fibresp	-0.480	0.147	-3.270	0.00
Non-TCE factors	swaps	-0.606	0.261	-2.320	0.02
-	(constant)	3.566	0.639	5.580	0.00

Appendix 3.2: Alternative regional models

Alternative Swedish models

Variable category	**Variable**	**Coefficient**	**Standard error**	**Z**	**P>|z|**
Uncertainty	uncert	-0.333	0.155	-2.140	0.03
Asset specificity	fibresp	-0.451	0.171	-2.640	0.01
	sp_type	-0.916	0.528	-1.740	0.08
-	(constant)	3.151	0.812	3.880	0.00

Variable category	**Variable**	**Coefficient**	**Standard error**	**Z**	**P>|z|**
Dummy variable	milltype	-0.677	0.400	-1.690	0.09
Uncertainty	uncert	-0.354	0.158	-2.240	0.03
Asset specificity	fibersp	-0.458	0.174	-2.640	0.01
-	(constant)	2.410	0.697	3.460	0.00

Alternative New Zealand models

Variable category	**Variable**	**Coefficient**	**Standard error**	**Z**	**P>|z|**
Asset specificity	balance	-0.605	0.223	-2.720	0.01
	forcon	-0.996	0.551	-1.810	0.07
	fibresp	-0.818	0.284	-2.880	0.00
-	(constant)	9.475	2.898	3.270	0.00

Variable category	**Variable**	**Coefficient**	**Standard error**	**Z**	**P>|z|**
Uncertainty	uncert	-0.406	0.204	-2.000	0.05
Asset specificity	balance	-0.589	0.247	-2.390	0.02
	forcon	-1.050	0.534	-1.970	0.05
	fibresp	-0.898	0.285	-3.150	0.00
-	(constant)	11.276	3.001	3.760	0.00

Appendix 3.3: Alternative sawmill and pulpmill models

Alternative sawmills models

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Transaction frequency	mills	-0.291	0.086	-3.390	0.00
Uncertainty	uncert	-0.305	0.145	-2.100	0.04
	pricevol	0.414	0.194	2.140	0.03
Asset specificity	fibresp	-0.551	0.196	-2.810	0.01
-	(constant)	2.370	1.085	2.180	0.03

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Dummy variable	region	0.524	0.586	0.890	0.37
Transaction frequency	size	-0.004	0.002	-1.790	0.07
	mills	-0.124	0.079	-1.570	0.12
Uncertainty	pricevol	0.540	0.213	2.540	0.01
	costprice	-0.513	0.368	-1.390	0.16
Asset specificity	fibresp	-0.468	0.230	-2.040	0.04
-	(constant)	1.567	1.088	1.440	0.15

Alternative pulpmills models

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Dummy variable	region	1.598	0.652	2.450	0.01
Transaction frequency	size	0.002	0.001	2.580	0.01
Asset specificity	forcon	-0.714	0.239	-2.990	0.00
	fibresp	-0.513	0.167	-3.080	0.00
-	(constant)	1.679	0.784	2.140	0.03

Variable category	Variable	Coefficient	Standard error	t	P>|t|
Transaction frequency	size	0.002	0.001	2.610	0.01
Asset specificity	balance	-0.372	0.168	-2.220	0.03
	fibresp	-0.628	0.151	-4.160	0.00
-	(constant)	1.576	0.878	1.790	0.07

Appendix 4: The surveys

1. Introduction

Welcome to this survey, and thanks for your participation.

The information you provide will be kept confidential. While the results of the study will be made public, it will only be a summary of many mill's responses, where the identity of individual mills will be hidden.

There are 21 questions - please answer them all to the best of your knowledge. The survey should take 10-15 minutes.

Please provide your participant code here:

2. Mill's log sourcing

The following questions are key to the survey, about what volume of logs the mill consumes, and how they are sourced.

1. How much of the mill's annual sawlog consumption is from each of the following sources? (please give percent, where total is 100)

From own forests (owned by same organisation as the mill, by share greater than 50%)

From long-term contracts (duration greater than 1 year)

From other sources (eg spot market)

2. Approximately what volume of sawlogs does the mill consume annually (please give in thousand cubic meters)

3. Number of buyers and sellers

These questions are related to the number of buyers and sellers in the market. If you are unsure of the exact answer to any of these questions, please estimate.

The term "fibre basin" is used here and elsewhere throughout the survey. By that I mean within a 120km radius of the mill.

3. What share of total productive forest resources in the fibre basin do the top 3 forest owners control?

- 0-10%
- 11-20%
- 21-40%
- 41-60%
- 61-100%

4. What share of total sawlog consumption in the fibre basin do the top three consumers use, in a typical year?

- 0-10%
- 11-20%
- 21-40%
- 41-60%
- 61-100%

5. What is the supply-demand balance in the fibre basin?

- Net export of >10% of total sawlog supply
- Net export of 0-10% of total sawlog supply
- Net balance of sawlog supply and demand
- Net import of 0-10% of total sawlog demand
- Net import of >10% of total sawlog demand

4. Asset specificity

These questions are regarding the level to which the mill is 'specific' to the resources in the fibre basin, i.e. how dependent it is on a specific type of resource. If unsure, please estimate.

Again, by fibre basin I mean within a 120km radius of the mill.

6. How much of the mill's annual sawlog need is harvested in the fibre basin in a typical year?

- 1-2 times mill's needs
- 3-4 times mill's needs
- 5-6 times mill's needs
- 7-10 times mill's needs
- 10+ times mill's needs

7. Does the organisation/individual that owns the mill own any other sawmills, pulp mills, panel mills, or other log-consuming plants within the fibre basin?

- No
- Yes. How many?

8. Which of the following species does the mill use? (please select all that apply)

- Radiata pine
- Douglas fir
- Other

9. How specific to the mill's operation are the sawlogs the mill consumes (in terms of dimensions, wood density, or other physical property)?

- 1 (Not at all specific)
- 2
- 3
- 4
- 5 (Highly specific)

5. Supply uncertainty

These questions relate to sawlog price volatility and supply uncertainty.

10. How volatile is the price of sawlogs on the open market, in your view?

- 1 (Not volatile, i.e. stable)
- 2
- 3
- 4
- 5 (Highly volatile)

11. With what level of certainty could the mill source (at affordable prices) all it's sawlog needs from the open market in a given year?

- 1 (Highly uncertain)
- 2
- 3
- 4
- 5 (Very certain / reliable)

6. Procurement costs

These questions relate to the costs of the mill's procurement operations.

12. How many procurement staff does the mill have working with log supply from non-integrated, non-contract sources (eg the spot market)?

13. How do forest owner associations impact the cost of procuring sawlogs in your fibre basin?

- No forest owner association / no impact
- Lower costs (eg through coordinated harvesting and marketing)
- Higher costs (eg by increasing forest owners' bargaining power)

14. How strong relationships do the mill's procurement staff tend to have with non-integrated, non-contract suppliers?

- 1 (Very weak)
- 2
- 3
- 4
- 5 (Very strong)
- No procurement staff

Forest-sawmill integration survey

7. Other factors

These are factors which may or may not have an impact on log sourcing decisions.

15. What is the ownership form of the mill/company?

- Private, single mill
- Private, multiple mills
- Public, single mill
- Public, multiple mills

16. When was the mill first established? (Please give first year of operation)

17. Which of the following products are manufactured at the mill?

- Mainly structural-grade lumber (eg for framing, packaging), i.e. at 60%+
- Mainly appearance-grade lumber (eg for furniture), i.e. at 60%+
- Both structural and appearance grade lumber, i.e. each at 40-60%

18. Does the owner of the mill own forest assets in another region, which can be used strategically to improve access to sawlogs in this fiber basin?

(For example, if sawmill owner #1 has forests in another region that are important to a sawmill owner #2, and #2 in turn owns forest assets important to #1, the two parties could make log exchanges, or "swaps")

- No
- Yes, to a limited degree
- Yes, to a significant degree

19. How significant are the costs of monitoring and enforcing log supply contracts, in your view?

- 1 (Not significant)
- 2
- 3
- 4
- 5 (Very significant)

20. How difficult is it to find out what the market price for sawlog is, in your view?

- 1 (Simple / easy)
- 2
- 3
- 4
- 5 (Very difficult)

21. What other factors influence your organisation’s decision on whether to own forest to supply the mill? (You may select several).

- Tax advantages
- Reduced capital intensity
- Focus on core business/competancies
- Risks of forest ownership
- “Soft” factors (eg organisation’s identity and affinity to forest assets)
- Other (please specify)

8. END OF SURVEY

Thank you very much for participating. You will receive a copy of the research paper on completion (early 2008).

Any feedback on the survey is gratefully received.

Glen O'Kelly
New Zealand School of Forestry
Canterbury University
glenokelly@hotmail.com

1. Introduction

Welcome to this survey, and thanks for your participation.

The information you provide will be kept confidential. While the results of the study will be made public, it will only be a summary of many mill's responses, where the identity of individual mills will be hidden.

There are 20 questions - please answer them all to the best of your knowledge. The survey should take 10-15 minutes.

Please provide your participant code here:

2. Mill's fibre sourcing

The following questions are key to the survey, about what volume of logs and chips the mill consumes, and how they are sourced.

1. How much of the mill's annual fibreconsumption is from each of the following sources? (please give percent, where total is 100)

Logs, from own forests (owned by same organisation as the mill, by share greater than 50%)

Logs, from long-term contracts (duration greater than 1 year)

Logs, from other sources (eg spot market)

Chips & residues, from own facilities (eg own sawmills)

Chips & residues, from long-term contracts (duration greater than 1 year)

Chips & residues, from other sources (eg spot market)

2. Approximately what volume of fibre does the mill consume annually (please give in thousand bone-dry metric tonnes)

3. Number of buyers and sellers

These questions are related to the number of buyers and sellers in the market. If you are unsure of the exact answer to any of these questions, please estimate.

The term "fibre basin" is used here and elsewhere throughout the survey. By that I mean within a 120km radius of the mill.

3. What share of total productive forest resources in the fibre basin do the top 3 forest owners control?

- 0-10%
- 11-20%
- 21-40%
- 41-60%
- 61-100%

4. What share of total chip and residue supply in the fibre basin do the top three suppliers control?

- 0-10%
- 11-20%
- 21-40%
- 41-60%
- 61-100%

5. What share of total pulplog and chip consumption in the fibre basin do the top three consumers use, in a typical year?

- 0-10%
- 11-20%
- 21-40%
- 41-60%
- 61-100%

6. What is the supply-demand balance in the fibre basin?

- Net export of >10% of total fibre supply
- Net export of 0-10% of total fibre supply
- Net balance of fibre supply and demand
- Net import of 0-10% of total fibre demand

- ◯ Net import of >10% of total fibre demand

4. Asset specificity

These questions are regarding the level to which the mill is 'specific' to the resources in the fibre basin, i.e. how dependent it is on a specific type of resource. If unsure, please estimate.

Again, by fibre basin I mean within a 120km radius of the mill.

7. How much of the mill's annual fibre need is harvested in the fibre basin in a typical year?

- ◯ 1-2 times mill's needs
- ◯ 3-4 times mill's needs
- ◯ 5-6 times mill's needs
- ◯ 7-10 times mill's needs
- ◯ 10+ times mill's needs

8. Does the organisation/individual that owns the mill own any other pulp mills, sawmills, panel mills, or other fibre-consuming plants within the fibre basin?

- ◯ No
- ◯ Yes. How many?

9. Which of the following species does the mill use? (please select all that apply)

- ☐ Radiata pine
- ☐ Eucalyptus
- ☐ Other

10. How specific to the mill's operation are the logs and chips the mill consumes (in terms of dimensions, fibre length, density, or other physical property)?

- ◯ 1 (Not at all specific)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Highly specific)

5. Supply uncertainty

These questions relate to fibre price volatility and supply uncertainty.

11. How volatile is the price of pulplogs and chips on the open market, in your view?

- ◯ 1 (Not volatile, i.e. stable)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Highly volatile)

12. With what level of certainty could the mill source (at affordable prices) all it's fibre needs from the open market in a given year?

- ◯ 1 (Highly uncertain)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Very certain / reliable)

6. Procurement costs

These questions relate to the costs of the mill's procurement operations.

13. How many procurement staff does the mill have working with fibre supply from non-integrated, non-contract sources (eg the spot market)

14. How do forest owner associations impact the cost of procuring pulplogs in your fibre basin?

- ◯ No forest owner association / no impact
- ◯ Lower costs (eg through coordinated harvesting and marketing)
- ◯ Higher costs (eg by increasing forest owners' bargaining power)

15. How strong relationships do the mill's procurement staff tend to have with non-integrated, non-contract suppliers?

- ◯ 1 (Very weak)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Very strong)
- ◯ No procurement staff

Forest-pulpmill integration survey

7. Other factors

These are factors which may or may not have an impact on log sourcing decisions.

16. When was the mill first established? (Please give first year of operation)

17. Does the owner of the mill own forest assets in another region, which can be used strategically to improve access to fibre in this fiber basin?

(For example, if mill owner #1 has forests in another region that are important to a mill owner #2, and #2 in turn owns forest assets important to #1, the two parties could make log exchanges, or "swaps")

- ◯ No
- ◯ Yes, to a limited degree
- ◯ Yes, to a significant degree

18. How significant are the costs of monitoring and enforcing fibre supply contracts, in your view?

- ◯ 1 (Not significant)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Very significant)

19. How difficult is it to find out what the market price for fibre is, in your view?

- ◯ 1 (Simple / easy)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Very difficult)

20. What other factors influence your organisation's decision on whether to own forest to supply the mill? (You may select several).

- ☐ Tax advantages

- [ ] Reduced capital intensity
- [ ] Focus on core business/competancies
- [ ] Risks of forest ownership
- [ ] “Soft” factors (eg organisation’s identity and affinity to forest assets)
- [ ] Other (please specify)

8. END OF SURVEY

Thank you very much for participating. You will receive a copy of the research paper on completion (early 2008).

Any feedback on the survey is gratefully received.

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Canterbury University
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