THE ECONOMICS OF NON-INDUSTRIAL TIMBER SUPPLY IN SOUTHERN AND CENTRAL FINLAND:
SPATIAL ROUNDWOOD MARKET ANALYSIS

by

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ABSTRACT

The majority of the roundwood processed by the highly concentrated forest products industry in Finland is supplied by over 350,000 non-industrial private forest owners [NIPF]. Since the beginning of the 1970s, the forest ownership objectives of these NIPF owner have diversified rapidly, and grown to include both timber and non-timber objectives. The potential impact of non-timber objectives on NIPF timber supply has created substantial concerns for the Finnish forest products industry. To explore the impact of these objectives, this thesis reviews and analyzes studies on the competitiveness of the Finnish roundwood markets in the context of other Scandinavian roundwood markets. The deficiencies of existing timber supply and demand models are reviewed, and these are then addressed in the development of a prototype mill-specific timber demand model [MSTD]. While important parameters such as roundwood price (at the roadside) were explored, the MSTD model is primarily based on mill characteristics such as distance to supply, mill capacity and mill type. The model describes wood procurement patterns with a high spatial resolution. It provides the basis for further model development, enabling the analysis of both purchasing behavior and producers criteria for selling, which will then allow for the evaluation of the potential impact of forest ownership objectives on timber supply in specific local and regional timber markets.
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1.0 INTRODUCTION

The majority of the roundwood processed by the highly concentrated forest products industry in Finland is supplied by over 350,000 non-industrial private forest owners [NIPF]. In the decades leading up to the year 2000, the forest ownership objectives of these NIPF owners have diversified rapidly, and grown to include both timber and non-timber objectives. The potential impact of non-timber objectives on NIPF timber supply has created substantial concerns for the Finnish forest products industry. In this context, the three objectives of this study were:

1. To analyze the current roundwood market structure in Finland;
2. To identify deficiencies in current models of NIPF timber supply;
3. To develop a prototype mill specific timber demand model [MSTD] which allows for the inclusion of forest ownership objectives and disaggregated roundwood market data.

To explore these objectives, first, the thesis reviews and analyzes studies on the competitiveness of roundwood markets in Finland and other parts of Scandinavia. Second, it evaluates existing models of NIPF timber and identifies deficiencies. Third, it examines patterns in the Finnish forest product sector wood procurement behavior. Fourth, it develops a prototype model to explain wood procurement based on variables such as distance to supply, mill capacity and mill type.

The empirical wood procurement data for the development of the MSTD model was provided by UPM-Kyömmene. UPM is one of the three largest integrated forest products companies in Finland, processing about 25% of the domestic roundwood
supply. The dataset covers the roundwood that was supplied to 105 mills in southern and central Finland, 31 of which were by UPM. While this dataset provides sufficient resolution for analyzing spatial timber flows, it is constrained by only partially integrating price information (see discussion in Section 3.1.1 and 4.1.3).

2.0 ROUNDWOOD MARKETS IN FINLAND
2.1 THEORY

A market can be defined as an institution where the production plans of the suppliers and the procurement plans of the buyers are being coordinated; the market price serves as the main signal for coordinating these plans (Bergen et al. 2002). The functioning of a market is dependent on its three main components: market structure, market behavior, and market results. Market structure is determined by the number and size of buyers and suppliers, as well as the production possibilities of the suppliers, the processing possibilities of the buyers, and the regulatory/institutional framework (Bergen et al. 2002). Market behavior describes the interactions among market participants, i.e. whether they regard the market price as an exogenous factor, or whether one participant tries to gain a competitive advantage with, for example, a strong focus on quality. The market results are the market price, the traded quantities, and the associated benefits for all market participants. These market components are linked in a dynamic system (Bergen et al. 2002; Linde 1992). This study will focus on the analysis of market structure as observed in spatial roundwood procurement patterns, since both market
behavior and market results are, to a large degree, determined by the structure of a particular market.

Markets are commonly separated into perfect and imperfect markets. In a perfect market, at a particular point in time all goods are being traded for the same price (law of one price). This is only possible for homogenous goods, where all market participants have equal access to information about the quality and the price of the good. Goods are homogenous, when no personal, spatial or temporal preferences exist among the market participants (Bergen et al. 2002).

Table 1 summarizes the nine commonly accepted market structures. Existing markets can also fall between the structures described below. Some of these theoretical market structures will be discussed to demonstrate the links between market structure and market results.

Table 1. Typology of market structures (from Linde 1992)

<table>
<thead>
<tr>
<th>Supplier(s)</th>
<th>Buyer(s)</th>
<th>Many</th>
</tr>
</thead>
<tbody>
<tr>
<td>Few</td>
<td>Limited Monopsony [d]</td>
<td>Bilateral Oligopoly [e]</td>
</tr>
<tr>
<td>Many</td>
<td>Monopsony [g]</td>
<td>Oligopsony [h]</td>
</tr>
<tr>
<td>One</td>
<td>Bilateral Monopoly [a]</td>
<td>Limited Monopsony [b]</td>
</tr>
<tr>
<td>Few</td>
<td>Limited Monopsony [d]</td>
<td>Bilateral Oligopoly [e]</td>
</tr>
<tr>
<td>Many</td>
<td>Monopsony [g]</td>
<td>Oligopsony [h]</td>
</tr>
</tbody>
</table>

A polypoly ([i], Table 1) is usually considered to be perfectly competitive. Each seller is too small relative to the total market supply to influence the product's market
price. Both suppliers and purchasers regard the market price as a fixed factor to which they respond by adapting their supply and demand quantities (Pearse 1990).

A monopsony¹ (Table 1) can be described as an imperfect market, with one buyer and many sellers of a particular product. A monopsonist can fix the price for which he/she is willing to buy a particular product, and the supplier will determine the quantity that he will sell at that particular price. Alternatively, the buyer can fix the quantity, and the suppliers will determine the price that they are willing to sell for (Bergen et al. 2002). In both cases, the result will be a particular combination of price and quantity that describes the supply behavior of the monopsonist. This point, where the monopsonist’s profit is maximized is called the “Cournot-Market-Equilibrium” (Bergen et al. 2002; Linde 1992). As it will be shown later, neither a polypoly nor a monopsony market structure is applicable to the Finnish roundwood market.

2.2 MARKET STRUCTURE IN SCANDINAVIA

2.2.1 Overview

Market theory suggests that imperfect markets will not provide the maximum benefit to society. Welfare losses are usually associated with imperfections such as asymmetric access to spatial markets or an imbalanced market structure (Størdal and Nyrud 2003). Markets in Sweden and Norway have many similarities to roundwood markets in Finland; therefore, relevant studies from these countries have also been

¹ A monopoly (Table 1, {c}) would result in similar market behavior and market results, with the roles of buyers and sellers being reversed.
reviewed (Framstad 1996; Toppinen 1998a; Ronnila and Toppinen 2000; Tilli et al. 2001; Lindstad 2002; Toivonen et al. 2002; Størdal and Nyrd 2003). In the following section, the structure of roundwood markets in Scandinavia will be discussed to highlight some of the concerns that have been raised about their competitiveness (Brännlund et al. 1985; Brännlund 1989; Hultkranz and Aronsson 1989; Bergman and Löfgren 1991; Hetemäki and Kuuluvainen 1992; Nordvall 1996; Toppinen 1998a; Bergman and Nilson 1999; Linden and Uusivuori 2000; Ronnila and Toppinen 2000; Størdal and Nyrd 2003). The Scandinavian timber markets appear to be highly integrated, forming single commodity markets for the major log assortments. For example, in the spruce market, timber prices are linked by strong and time-invariant relationships, which can be described by a simple arbitrage equilibrium (Thorsen 1998). However, it should be noted that even in integrated markets, prices may fluctuate independently as long as the price variation does not exceed the transaction costs between two locations (Toivonen et al. 2002).

Markets for pulpwood and sawlogs are commonly analysed separately (e.g. Brännlund et al. 1985; Toppinen 1998b). However, this may not be appropriate since there are some dynamic links between these two markets; for example, sawlogs are sometimes substitutes in pulp and paper production. In contrast, sawmills are generally unable to substitute pulpwood for sawlogs (Nyrd 2002). From the suppliers point of view and in mature stands, pulpwood and sawlogs are usually produced jointly, with the forest owner having the option to adjust the amount of pulpwood harvested depending on

\footnote{In this context Scandinavia refers to Norway, Sweden, and Finland; neither Denmark nor Iceland have substantial forest resources (FAO 2001).}
the market prices (Brännlund 1989; Nyrud 2002; Størdal and Nyrud 2003). This adjustment can be made during harvesting operations when the logger/harvester operator cuts the tree into logs (pulpwood and sawlog assortments) according to the desired product mix (Størdal and Nyrud 2003).

2.2.2 Scandinavian Pulpwood Markets

In 1991, the Swedish pulpwood market was almost completely monopsonized, with 75% of the pulpwood bought through a single intermediate purchasing agent (Bergman and Løfgren 1991; Bergman and Nilson 1999). The pulpwood price was set in annual negotiations between one organization representing the sellers and one representing the buyers. The buyer is usually the stronger party, therefore the market is best described as containing strong monopsonistic features (see [g], Table 1) (Brännlund et al. 1985; Brännlund 1989). As the price is set before the cutting plans of the sellers are known, and since the terms of trade contain no explicit clause on quantities, the quantity outcome is uncertain. There are potential backstop markets, such as the industry’s own forests, the market of standing timber for sale, and an international market for pulpwood, where additional wood can be bought, if the outcome in the ordinary market results in an insufficient wood supply (Bergman and Løfgren 1991). Binkley (1991) raised the concern that, through the use of company-controlled forests, a firm could exert control over the price paid for additional roundwood on the open market. This would result in a financial loss for the participants in the open market that, in percentage terms, exceeds...
the amount of roundwood supplied from company-owned forests. However, other studies have shown that cuttings in industry-owned forests were positively correlated with cuttings in private forests; therefore the forest industries have not used their own forest as a backstop by implementing countercyclical harvesting patterns to supplement for NIPF timber supply (Brännlund et al. 1985; Brännlund 1988). Similar results were observed in the use of imported wood, where companies used imported wood not as a backstop market for exerting market power on the domestic pulpwood market, but for compensating unexpected fluctuations in domestic supply (Bergman and Löfgren 1991; Bergman and Nilson 1999). There is strong evidence that the firms act simultaneously in both domestic and import markets, and that the wood inventory at the mill location is used very consciously as a means to handle supply uncertainty. The reason is probably the extremely high costs involved in running out of roundwood, which have been labelled "stockouts". Wood is, formally speaking, an essential production factor for the forest industry that, combined with the high fixed costs of operating a processing facility, make stockouts a major disaster (Bergman and Löfgren 1991). The reason that the world markets do not play a more significant role in compensating for domestic supply fluctuations is that the pulp and paper industry imports roundwood from a relatively thin market where they cannot increase the purchased volume significantly on short notice (Bergman and Löfgren 1991). Nyrud (2002) found similar results for the Norwegian pulpwood market. Domestic price levels were derived from international price levels, thus rejecting the hypothesis that pulpwood purchasers were able to practice price discrimination by segmenting domestic and import markets. However, other studies did
find some evidence of market imperfections in the Scandinavian roundwood markets (e.g. Johansson and Löfgren 1983; Brännlund 1989; Nordvall 1996).

Johansson and Löfgren (1983) concluded that the Swedish roundwood market could not be treated as a “single price market”, since the typical company purchases wood from a variety of sources, including company-owned forests, open roundwood markets, standing timber sales, and imports. Brännlund et al. (1985) found that the price of pulpwood was mainly influenced by the demand side. Forest owners responded by adjusting supply, thus indicating a monopsonistic or oligopsonistic (g,h), Table 1) market structure. In the case of perfect price discrimination, the buyer would capture all producer surplus since he would purchase each successive unit of wood for the minimum amount the forest owner is willing to sell for (Brännlund 1989). Studies of the Norwegian pulpwood market concluded that, at least during the period 1984 to 1992, the market was not competitive since national industrial roundwood prices were determined in centralized negotiations between buyers’ and sellers’ associations. Mergers in the Norwegian pulp and paper industry during the 1990s were significant enough for the firms to increase their ability to perceive the effect of their own wood demand on the market price of wood; thus both obtaining and exercising market power (Kallio 2001; Størdal and Baardsen 2002).

Overall, due to the asymmetry of the pulpwood markets in Scandinavia, theory suggests strong market imperfections; however, most studies rejected this hypothesis since both volumes traded and market prices were close to what would be expected under
perfect competition (Koskela and Ollikainen 1998; Toppinen 1998a, 1998b; Bergman and Nilson 1999; Ronnila and Toppinen 2000; Tilli et al. 2001).

2.2.3 Scandinavian Sawlog Markets

In contrast to the asymmetry of the Scandinavian pulpwood markets, the sawlog market seems to be relatively well balanced. For example, the number of buyers is relatively high in the Finnish sawlog market; there are 170 large and medium-sized and over 2000 small sawmills (Siekkinen and Pajuoja 1992; Toppinen 1998; Kallio 2001). The ownership of the large and medium scale sawmilling industry is concentrated, since the mills owned by the three biggest forest industry companies comprise about one half of the total sawnwood production (Toppinen 1998b). Therefore, in Finland, the competitive equilibrium market assumption is more likely to be met in the sawlog sector than in the pulpwood sector (Toppinen 1998b; Kallio 2001), largely because of the small-scale sawmills. Signs of market imperfections were only identified in studies of the Swedish sawlog market, where price discrimination was detected for the late 1970s and early 1980s (Johansson and Löfgren 1983; Brännlund et al. 1985); however, policy changes have been made to address price discrimination.

In Finland a comprehensive price recommendation system did exist between 1978 and 1991. Once the system was removed, Toppinen (1998a) found that the equilibrium assumption was well suited to the Finnish sawlog market, since disequilibria was corrected through the adjustment of both sawlog quantities and prices. Other studies

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3 Average annual capacity about 300 m³.
found that these results are consistent with behaviour in the Swedish sawlog market (e.g. Brännlund et al. 1985; Brännlund 1989, 1991; Brännlund and Löfgren 1992).

Centralized price negotiation systems are still in place in the Norwegian sawlog market, where it is assumed that buyers and sellers had roughly the same negotiating power. Theory suggests that, in Norway, they created an almost perfect bilateral monopoly (\{a\}, Table 1), which would result in widely fluctuating volumes, but market prices close to the competitive level. However, Størdal and Baardsen (2002) were not able to identify these predicted volume fluctuations in empirical data of the Norwegian sawlog market. They suggested that the assumptions of the bilateral monopoly did not hold true, since the seller did not have the ability to control the volume supplied to the market. The total volume supplied to the market was determined by the aggregate harvesting plans of individual NIPF owners, and not by the Forest Owners’ Association that was acting as the common selling agent for all NIPF owners.

Since 1992 two policy changes have contributed to more competition in the Norwegian roundwood markets. First, a ruling by the European Free Trade Agreement Surveillance Authority forced the ownership associations to merge into larger units and to abandon their influence on regulating members’ harvest or equalizing prices. Second, market driven mergers and acquisition activities greatly reduced the number of firms competing in the sawmilling sector. The emergence of few, relatively large agents on both sides of the market has increased the competitiveness of the market. Possibilities to exercise market power are limited in situations where equal numbers of buyers and sellers are participating in the market (\{a\}{e}\{i\}, Table 1) (Størdal and Baardsen 2002;
Størdal and Nyrud 2003). This coincides with the finding that the Norwegian sawmilling industry has not been using the international market as a backstop for regulating domestic demand (Størdal and Nyrud 2003).

2.3 MARKET STRUCTURE IN FINLAND

The forest sector, including both the forest industry\(^4\) and forestry\(^5\), contributes substantially to the Finnish economy. Although the share of the forest industry in Finnish exports has declined steadily over the past decades it still accounts for 27% of all exports, valued at approximately € 13.3 billion\(^6\). In comparison, roundwood exports are negligible, accounting for only 0.6% of all exports (METLA 2001). In 2000, the forest sector accounted for 2.3% of the Finnish gross domestic product [GDP], with the forest products industry contributing an additional 6%. This is equivalent to € 2.6 billion and € 6.9 billion, respectively. The forest products industry contributed approximately 23% of the total value added in manufacturing in Finland. In addition, indirect economic impacts occur through the forest sector's demand for input factors, thus contributing to the value added in other sectors, such as construction, and machinery and equipment manufacturing.

By comparison, the direct contribution of the forest sector to national employment is relatively small. Employment in both the forest and forest products sector

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\(^4\) Forest industry is defined as the manufacturers of wood and wood products, as well as pulp, paper, and paper products (METLA 2001).

\(^5\) Forestry refers to silviculture, harvesting, and related service activities (METLA 2001).

\(^6\) All monetary values are given in Euro [€]. The average interbank conversion rates from January 1, 2000 to December 31, 2000 were (OANDA 2003): 1 € ≈ USD 0.92 ≈ CAD 1.37
has declined steadily over the last decades. In 2000, only about 1% of employment was
provided by forestry (24,000 permanent employees), while the forest products sector still
accounted for 2.8% of employment (72,000 permanent employees) (METLA 2001).
However, in rural Finland, forestry and small to medium scale timber processing have
special importance to providing both working opportunities and income from timber sales
to rural areas. Particularly the development of value-added products has improved the
competitiveness of these small to medium scale processing facilities in an industry
dominated by large scale industrial manufacturing (Toppinen 1998a).

The Finnish forest industries have expanded their capacity substantially over the
last 30 years. From 1970 to 2000 roundwood consumption increased by almost 40%,
from 53.93 million m$^3$ in 1970 to 74.45 million m$^3$ in 2000. For solid wood products over
the same period, the production of sawn goods increased by 84% to 13.4 million m$^3$,
almost doubling the 1970 output. The production of plywood and particle board increased
by 65% and 21%, respectively, while the output of fibreboard dropped by almost 60%.
Over the same period, the production of pulp almost doubled from 6.2 million tons to
11.9 million tons. The most substantial growth could be observed in the production of
paper and paper board, which more than tripled to a capacity of 13.5 million tons in the

The roundwood required by the Finnish forest products industry can be procured
in both domestic and international roundwood markets. Although the Finnish forest
sector is heavily export oriented, it procured 84% of the total roundwood demand from
domestic markets in the year 2000. More than 90% of the spruce and pine demand was
met domestically. Imports are mostly relevant to birch roundwood demand (Table 2), while other hardwoods, such as aspen and poplar, only play a minor role.

Table 2. Consumption and sources of roundwood in Finland (from METLA 2001).

<table>
<thead>
<tr>
<th></th>
<th>Consumption (million m$^3$)</th>
<th>Domestic roundwood as share of consumption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine</td>
<td>25.93</td>
<td>92</td>
</tr>
<tr>
<td>Spruce</td>
<td>30.71</td>
<td>93</td>
</tr>
<tr>
<td>Birch$^a$</td>
<td>17.81</td>
<td>57</td>
</tr>
<tr>
<td>Total</td>
<td>74.45</td>
<td>84</td>
</tr>
</tbody>
</table>

The volumes of imported wood have been increasing steadily since the mid-1970s, largely due to technological advances in the pulp industry that enabled the use of non-coniferous wood. This increasing demand could not be met by the domestic market, thus resulting in substantial imports of hardwood logs. Currently, about 80% of the imported birch roundwood originates from Russia and the Baltic States. The increasing role of imported birch pulpwood is likely to have encouraged investments in the pulp and paper industry as well as increased the demand for domestic birch roundwood. This has created additional benefits to the Finnish economy, providing both increased employment and additional earnings from pulp and paper exports (Tilli et al. 2001).

The continued restructuring of the Finnish forest industry has led to concerns over the concentration of market power. While the larger firms usually benefit from mergers and acquisitions through improved cost efficiency, the resulting large market

$^a$ Minor volumes of other hardwoods included.
areas may also reduce spatial competition among firms (Kallio 2001, Størdal and Baardsen 2002). This reduction of competition would occur when the larger forest company acquires smaller competitors that have traditionally procured roundwood in the same area as the larger company, thus reducing the number of potential trading partners available to NIPF owners willing to sell roundwood in that particular area. The resulting market imperfections may have far reaching consequences. If market imperfections keep price levels below the competitive level, these prices would send the wrong signals to market participants. As a result too little timber would be supplied, which in turn would also affect capacity adjustment, employment levels, and choice of production technology. The market for forestland would also be affected negatively, since the value of standing timber provides important signals for the valuation of forested land (Binkley 1991).

2.3.1 Processing Sector

In recent decades, the Finnish pulp and paper sector has become increasingly integrated, both horizontally and vertically. There have been a series of acquisitions and mergers, leading to a highly concentrated industry where the three main competitors, UPM-Kymmene, Stora-Enso, and Metsä-Serla, share 80-90% of the pulpwood market. Of these three companies, only UPM-Kymmene and Stora-Enso procure the majority of

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7 Horizontal integration: Integration of similar companies, designed to either reduce competition between these companies, or to increase market power (e.g. several pulpmills coordinating their wood procurement) (Wohe 1996).

8 Vertical integration: Integration of companies where each company provides input factors for another company of the same group (e.g. a forest products company owning forests, pulpmills, and paper mills) (Wohe 1996).
their individually negotiated stumpage and delivery sales (Toppinen 1998a). Metsä-Serla acquires its wood through a cooperation agreements that exist between its wood procurement branch Metsäliitto Osuuskunta and non-industrial private forest owners (Toppinen 1998a; Metsäliitto 2001). Metsäliitto Osuuskunta is jointly owned by approximately 127 000 members, mainly non-industrial private forest owners. Membership is open to all private persons and corporations owning a minimum of three hectares of productive forest land in Finland; together, they own 5.1 million hectares of forest land throughout Finland. Although the members are under no obligation to sell timber to Metsäliitto, they do receive bonus payments based on the volumes sold to Metsäliitto during the previous four years. In 2000 these bonus payments amounted to €1.3 million, or €10 per member (Metsäliitto 2001). However, it is unlikely that all members qualify for these bonus payments; therefore the actual payments to qualifying members will most likely be substantially higher.

In addition to their own operations, both UPM-Kymmene and Metsäliitto have invested some of their capital in shares of other forest companies, while Stora Enso has adapted an aggressive strategy of takeovers and acquisitions (Metsäliitto 2001; Stora Enso 2001; UPM-Kymmene 2001). These strategies can result in substantial crossover in ownership and investment structure. One example of this crossover is the 47% stake that UPM-Kymmene controls in Metsä-Botnia AB, a subsidiary of Metsäliitto Osuuskunta (Metsäliitto 2001; UPM-Kymmene 2001).

One of the main reasons for this high level of concentration is that the establishment of a pulpmill requires a substantial initial investment, thus forming a
relatively high barrier to entry in the market (Brännlund 1989; Toppinen 1998b; Kallio 2001). In contrast, the initial investment necessary for the establishment of a new sawmill is much lower, suggesting that more competitors may be able to enter this market (Toppinen 1998b). Some evidence of these low barriers to entry can be seen in the high number of small operators in the Finnish sawmilling sector, where the three biggest forest products companies, UPM-Kymmene, Stora-Enso, and Metsäliitto, only control approximately half of the sawn wood capacity in Finland.

Depending on the wood assortment, the level of buyer concentration also varies regionally. Generally the level of buyer concentration was found to be higher than average in northern Finland, and lower than average in southern and central Finland (Västilä and Peolola 1997).

The big forest products companies purchase the majority of their wood directly from the landowner since intermediary agents purchasing and re-selling wood are almost nonexistent in Finland (Toppinen 1998b). In this context, incentive programs such as the bonus payments used by Metsäliitto or the forest management services offered by UPM Kymmene can contribute substantially to securing a continuous supply of roundwood for the processing sector (Metsäliitto 2001; UPM-Kymmene 2001). Creating an internationally competitive industry based on roundwood predominately procured from this highly diverse group of non-industrial forest owners has created some unique

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9 The ownership of both sawmills and pulpmills can be described as a special case of vertical integration, since the by-products of sawnwood production (wood chips and sawdust) can be used as a fibre source for the production of pulp. The economics of the wood chip market in Finland differ substantially from the roundwood markets (See Ronnila and Toppinen (2000) for a detailed analysis).
challenges for the Finnish forest products sector, not the least of which is the contractual arrangements between the concentrated wood processing sector and NIPF owners.

2.3.1 Non-industrial Private Forests

2.3.1.1 Background

While small-scale forestry has always been relatively common in Finland, the emergence of NIPF as the dominant form of forest ownership is closely linked to the history of the country. The majority of NIPF holdings were created during periods of social unrest in Finland. After centuries of foreign ruling (Swedish and Russian) Finland became independent following the October Revolution in 1917. The land reform before, and immediately following Finnish independence resulted in a large number of small farms being created to provide an improved livelihood to the rural population. A similar initiative occurred post World War II, when a resettlement program was initiated for people displaced from the territories ceded to the Soviet Union as well as for other groups disadvantaged by the war (e.g. repatriated soldiers with family, disabled servicemen, war widows) (Tykkyläinen 1996). The income from these small farms was insufficient to support a household, therefore the agriculture income had to be supplemented with access to household wood supply and income from stumpage earnings (Järveläinen 1999; Saastamoinen and Pukkala 2001). In addition to providing supplement income for otherwise unprofitable farms, these small forest holdings were designed to provide a seasonal labour force for logging. Since these land holdings were too small to employ the owner full-time during the winter months, forest companies could rely on this readily
available labour force. However, the introduction of motor-manual\textsuperscript{10} and, in the 1970s, mechanized timber harvesting techniques\textsuperscript{11} drastically reduced the demand for manual labour. By the year 2000 almost 95\% of the commercial roundwood volume was harvested mechanically (METLA 2001; Saastamoinen and Pukkala 2001). The resulting socio-economic changes in the Finnish society are consistent with the occupational and regional differentiation and urbanization that has occurred in other industrialised countries (Jansen and Hetsen 1991; Macie 1997). As a result, one of the major trends in NIPF ownership in Finland has been the emergence of non-farming, rural and urban absentee households as the most prominent ownership category. The tradition of handing down the forest property within the family has lead to an increasingly fragmented ownership structure, with absentee and joint ownership becoming relatively frequent (Ripatti and Järveläinen 1997, Karppinen 1998a). Over the past decades, a slightly imbalanced development of average property sizes has occurred, with the number of medium-sized forest holdings (20-50 hectares) decreasing and the number of both smaller and larger holdings increasing. This trend can mainly be attributed to the transfer of some forest holdings to people who already own forest, as well as to legislation that, until 1997, gave farmers the right of first refusal when the sale of agricultural or forest land was concerned (Saastamoinen and Pukkala 2001, Ripatti 1999).

The combination of agriculture and forestry has created a particular “way of life” for many Finnish families. While the role of forests as an additional source of income for farming households has decreased steadily, it is still a substantial source of

\textsuperscript{10} Chainsaws.
\textsuperscript{11} Feller bunchers, harvesters, etc.
income for rural households, especially for larger cash outlays (Saastamoinen and Pukkala 2001). This “way of life” has continued even in part of North America (e.g., in the Finnish immigrant communities in the Upper Great Lakes region in northern Wisconsin). Some of these families who immigrated in the late 18th century have successfully recreated their traditional way of life by combining winter timber production with dairy farming. These families still strongly identify with their Finnish heritage and this particular “Finnish way of living” (Bliss and Martin 1989).

2.3.1.2 Current relevance of non-industrial private forestry

The majority of the roundwood used by the Finnish forest products industry is produced on NIPF holdings. NIPFs are held privately by individuals or corporations that do not operate a primary wood-processing facility (Gregory 1987; Helms 1998). In 2000, 53.6 million m³, or approximately 87% of commercial roundwood removals in Finland, originated from private forests (89% of sawlogs; 83% of pulpwood)(METLA 2001). The annual gross stumpage income of private forests (including forests owned by municipalities, parishes, and other collective bodies as well as state forests not controlled by the Finnish Forest and Park Service) was € 1.65 billion. On average, NIPF in Finland were operating profitably in 2000, generating an operating surplus of € 106 per hectare. Net earnings were highest in eastern Finland (157 €/ha), followed by western Finland (131 €/ha) and northern Finland (35 €/ha). Direct state subsidies did not affect the profitability significantly, accounting for only € 3.70 per hectare (METLA 2001).
NIPF ownership in Finland is characteristically small scale, with an average property size of 25 hectares (22 ha in southern Finland, and 36 ha in northern Finland). Currently there are about 450,000 forest holdings in Finland (350,000 in southern Finland, 100,000 in northern Finland) (METLA 2001). The ownership distribution varies significantly throughout the country (Table 3).

Table 3. Forest ownership distribution in Finland (from METLA 2001).

<table>
<thead>
<tr>
<th>Forest Ownership</th>
<th>Southern Finland [%]</th>
<th>Northern Finland [%]</th>
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</thead>
<tbody>
<tr>
<td>Non-industrial private</td>
<td>75</td>
<td>44</td>
</tr>
<tr>
<td>Companies</td>
<td>12</td>
<td>46</td>
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<tr>
<td>State</td>
<td>7</td>
<td>5</td>
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<tr>
<td>Other</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Non-industrial private ownership and company ownership are concentrated in southern Finland, while state owned forests are mainly located in the northern region (METLA 2001).

2.3.2 Ownership Objectives in Non-industrial Private Forestry

In Finland, NIPF owners have traditionally had both timber and non-timber objectives. This section will describe NIPF ownership objectives found in Finland and analyze their effects on the forest landowners ability to meet their specific economic and ecological objectives.
NIPF ownership objectives can be significantly different even when situations appear to be similar. For example, in Finland regional differences are so substantial, that the majority of studies have divided the country into a northern and a southern part (Meklas 1985; Sevola 1997; Karppinen 1998a, 1998b; METLA 2001). Besides climatic differences, the northern region differs from the southern one socially, economically and culturally (Karppinen 1998a).

For examining ownership objectives, the administrative boundaries of the forestry centers (Figure 1) will be followed even though they do not match the boundaries of the provinces.
Figure 1. Forestry centres in Finland (from METLA 2000).

The forestry centers Kainuu, North Ostrobothnia, and Lapland (forestry center #11-13) are referred to as northern Finland; the forestry centers Coast, Southwest Finland, Hämä-Uusimaa, Kymi, Pirkanna, South Savo, South Ostrobothnia, Central Finland, North Savo, and North Karelia (forestry center #1-10) are referred to as southern Finland (METLA 2000).
Structural change\textsuperscript{12} has been more rapid and more severe in NIPF in the north, where the proportion of non-farmers and absentee owners is much higher. One of the main factors contributing to this development has been the failure of the resettlement efforts following World War II (see also chapter 2.3.1), which resulted in numerous unprofitable farms (with forests) being abandoned (Selby 1975; Karppinen 1998).

More recently a combination of rapid socio-economic changes and frequent transfers and subdivisions of forest lands have created a highly diverse group of NIPF owners, ranging from traditional farmers/foresters living on their property to absentee owners living in large urban centers. These diverse backgrounds introduce a wide range of objectives into the management of the Finnish forest resources (Karppinen 1998a). The long-term objectives of individual forest owners are relatively resistant to change, but transfer of ownership does introduce new objectives into forest management (Durkheim 1933; Rescher 1969; Inglehart 1977). Overall, the new ownership objectives will reflect the prevailing public opinion about the appropriate balance between nature conservation and economic utilization of forest resources (Karppinen and Hänninen 2000).

In general, the ownership objectives are less diverse in the north of Finland than in the south, since the north can be classified as the more traditional society. Karppinen (1998) was able to identify distinct groups of NIPF owners, based on their ranking in terms of non-timber objectives (such as outdoor recreation, solitude and meditation, aesthetic value), sales income and self-employment opportunities, and economic security

\textsuperscript{12} Structural change is defined as any change of the market structure; in this case, structural characteristics such as property size and landowner occupation are included (Schwarzbauer 1998).
and asset motives (such as funding for investments, security against old age, hedging motives) for owning forest land (see Table 3). For southern Finland, he described four categories of NIPF owners: multiobjective owners, recreationists, self-employed owners, and investors. It was not possible to identify these four distinct groups in the northern part of the country, suggesting that forest ownership objectives may be more homogenous for NIPF owners in northern Finland (Karppinen 1998a). While a diversification of forest ownership objectives was observed, it was not possible to establish a strong link between forest ownership objectives and overarching values such as materialism (forests as a means to increase the material standard of living), humanism (using forests to promote cultural aspects), mysticism (experiencing the unity of man and nature in the forest), and primitivism (rejecting all human privileges in nature) (Karppinen 1998b).

The similar diversification of ownership objectives was found in studies of NIPF in Sweden. In a study of forest ownership objectives, Ask and Carlsson (2000) found that 90% of the landowners considered timber production a secondary objective for an average of 7% of their property. The areas where timber production was a secondary objective usually had a relatively high conservation value (e.g. close proximity to key habitats, aesthetics). While the proportion of areas with primarily non-timber objectives is relatively low, the majority of NIPF owners do consider non-timber objectives a priority for a portion of their land holding. This indicates that both timber and non-timber objectives are being accepted as valid forest ownership objectives. While Ask and Carlsson (2000) studied a snap shot of the ownership objectives, Lönnstedt (1997)

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13 Only 29 NIPF owners were interviewed for this study. Interviews were carried out in 1996.
considered the potential for ownership objectives to change over the duration of ownership. He identified the economic and ecological preservation and development of the property as the overarching goal, while the relative importance of timber and non-timber objectives changed over the duration of ownership. In the initial phase, following the acquisition of a forest property, economic factors dominate since the landowner normally has significant financial needs. In the next phase, stewardship, non-timber objectives become more prominent, with the harvesting rates usually falling below the long-term sustainable yield. In the final phase, when the property is usually sold or passed on within the family, non-timber objectives clearly dominate forest management decisions, resulting in relatively infrequent harvesting activities. The length of these phases can vary considerably (Kuuluvainen and Salo 1991; Lönnstedt 1997).

In a study of NIPF owners in Georgia, USA, Hyberg and Holthausen (1989) concluded that utility maximization was better suited to describing NIPF behavior than a profit maximization model, since NIPF owners seek both monetary and nonmonetary returns on their forest investments. This is consistent with studies of NIPF owners in Wisconsin and in Illinois, where non-timber objectives were generally found to be more important than timber objectives (Young and Reichenbach 1987; Bliss and Martin 1989).

The changing demographics of NIPF owners as well as the potential impact of these forest ownership objectives on NIPF timber supply have been a major concern for the forest products sector in Finland (Young and Reichenbach 1987; Bliss and Martin 1989; Kuuluvainen and Salo 1991; Newman and Wear 1993; Kuuluvainen et al. 1996; Amacher 1997; Lönnstedt 1997; Toppinen 1998b; Karppinen and Hänninen 2000;
Hyttinen 2001; Bolkesjø and Baardsen 2002). For example, an increased focus on non-timber values may decrease the area available for commercial harvesting, or reduce the timber yield per hectare by requiring alternative harvesting techniques (Karppinen 1998); or, NIPF owners who are less dependent on income from their forests, may reduce the timber harvest level (Saastamoinen and Pukkala 2001).

Given these uncertainties, the next section will explore the mutual dependencies that exist between NIPF owners and the forest industry and assess how the MSTD model can help examine some of the issues associated with current roundwood market models.

2.4 LINKAGES

2.4.1 Non-industrial Private Forest Owners and the Forest Industry

The relationship between NIPF owners and the forest products industry in Finland is currently characterized by mutual dependencies. NIPF owners usually do not have the resources to market their wood beyond the local or regional level. With the exception of hunting rights, non-timber forest products are difficult to market as a source of income. Therefore, timber sales are the only option for generating forest-based income; at the same time, the forest processing sector is very reliant on NIPF owners for the majority of its timber procurement. The effectiveness of traditional forestry assistance programs as well as an increased reliance on international markets for roundwood for balancing some of the fluctuations in the domestic markets remains to be seen. Another possible approach to reducing supply uncertainties is the development of long-term
relationships between independent NIPF owners and the forest products industry. In Finland this strategy has already been employed by both Metsäliitto and UPM-Kymmene (Metsäliitto 2001; UPM-Kymmene 2001). Metsäliitto offers bonus payments for landowners who supplied wood to the company for a minimum of four consecutive years. UPM-Kymmene employs a different strategy, offering forest management services to NIPF owners.

The rapid regional differentiation of NIPF owners between northern and southern Finland provides some indication as to how quickly the focus of NIPF forest management may shift from generating additional household income to non-timber amenities. Ensuring a steady supply of timber for their processing facilities has become a major challenge for the Finnish forest products industry given the shifting ownership objectives (e.g. Newman and Wear 1993; Toppinen 1998a). Current models have not been able to adequately describe the variability of NIPF timber supply; therefore, this study has developed an alternative approach to better understand the dynamics between sellers and buyers in the roundwood market.

2.4.2 Contractual Arrangements

The structure of the Finnish roundwood markets has changed substantially over the last few decades. For most of the period between 1978 and 1999, stumpage prices were negotiated collectively between the forest owners’ and forest industry’s associations. The comprehensiveness of this centralized negotiating system decreased
over time, until being eliminated in 1999. The system collapsed for the first time in 1991, but was reinstated in 1994. Following the reinstatement of nationwide price negotiations in 1994, Finland was split into four separate price regions in 1995. In 1997, the price negotiations were held separately between the forest owners’ associations and representatives of the different forest companies. These price negotiations became less restrictive over time and turned into discussions on expected price development. The centralized negotiation system was finally abandoned in 1999 when the Finnish Competition Agency prohibited all forms of centralized negotiations in the Finnish roundwood markets (Tilli et al. 2001). The impact of these centralized price negotiations has been studied frequently, especially in studies of the Finnish and Norwegian roundwood markets (Johansson and Löfgren 1983; Bergman and Löfgren 1991; Brännlund 1989; Sexton 1990; Brännlund 1993; Toppinen and Kuuluvainen 1997; Koskela and Ollikainen 1998; Ronnila and Toppinen 2000; Uusivuori and Kuuluvainen 2001).

Today the big three forest companies in Finland (UPM-Kymmene, Stora Enso, Metsäliitto) purchase the majority of their roundwood directly from the landowner, since intermediary purchasing agents are almost nonexistent and the centralized price negotiation system had been abandoned completely (Toppinen 1998b, Tilli et al. 2001). Delivery sales\(^\text{14}\) only play a minor role in the Finnish market, since stumpage sales\(^\text{15}\) accounted for more than 80% of the commercial roundwood (METLA 2001). Therefore,

\(^\text{14}\) In delivery sales, the seller is responsible for the harvest of the timber and the delivery to the mill gate.
\(^\text{15}\) In stumpage sales (standing timber sales), the buyer is responsible for the harvest of the timber and transportation to the mill.
a forest company has to negotiate numerous individual harvesting contracts in order to meet the majority of their roundwood demand with timber harvested on NIPF lands. The content of these individually negotiated contracts between NIPF owners and the forest industry can vary substantially; giving the landowner the ability to ensure that his/her timber and non-timber forest ownership objectives are met during harvesting operations. Negotiating such a high number of individual harvesting contracts imposes substantial transaction costs on both forest owners and the forest industry.

2.5 TIMBER SUPPLY MODELLING

2.5.1 Existing Timber Supply Models

Most studies on NIPF timber supply have concentrated almost entirely on market signals, such as interest rates, or the relative prices of inputs (e.g. roundwood, energy) and outputs (e.g. sawn wood, pulp, and wood panels), as well as biophysical parameters, such as standing timber inventories and growth rates. Following is a brief review of a) traditional econometric models of NIPF timber supply, and b) existing models integrating selected landowner characteristics.

In Scandinavia, roundwood prices and interest rates have usually been regarded as the main determinants of NIPF timber supply (Young and Reichenbach 1987; Brännlund 1988; Hultkranz and Aronsson 1989; Lönnstedt and Svensson 2000; Kuuluvainen et al. 1996; Kuuluvainen and Tahvonen 1997). Furthermore, Kuuluvainen 16 In 2000, UPM-Kymmene reported 39,600 individual sales contracts with an average volume of 330 m³ (UPM-Kymmene Forest 2000).
et al. (1996) assumed that the effects of forest ownership objectives were small (up to 1 m³/ha/year) compared to the effects of market price signals and standing inventory. However, most of the variance in the observed harvesting behavior of NIPF owners remained unexplained in their model; variations in the ownership objectives were suggested as an explanation.

Løyland et al. (1995) reported that harvesting activities were positively related to both changes in roundwood prices and subsidies available for forest activities (e.g. development of forest management plans). While the implications may vary, government subsidies for forestry related activities are relatively common throughout Scandinavia and some parts of the United States (Carlén and Löfgren 1986; Brännlund 1990; Hultkrantz 1991; Framstad 1996; Mehmood and Zhang 2002). For NIPF owners in Sweden Bergman (1992) reported that the level of standing inventory had larger effect on harvesting levels than roundwood prices.

Comparing the timber supply behavior of industrial and NIPF owners in the southeastern United States, Newman and Wear (1993) found that, although a common production function was rejected, both types of forest owners were following a profit maximization behaviour. Both NIPF and industrial forest owners responded to changing market conditions in the long run, with NIPF placing a higher shadow value on their timber and forestland assets than industrial owners. This may be partly due to the relatively high priority given to the production of nontimber forest products on NIPF lands (Lönnstedt and Svensson 2000, Kuuluvainen and Tahvonen 1997). The sunk costs associated with the preparation of existing forest management plans were identified as the
key factor limiting short-term responses to changing market conditions. Only major changes in market conditions will impact the short-term timber supply, since in these cases the benefits of adapting timber supply will outweigh the costs of changing the forest management plans (Lönnstedt and Svensson 2000).

It should be noted that perfect capital markets are one of the basic assumptions of many NIPF timber supply models. This assumption is rejected in some studies of Scandinavian NIPF owners where the landowners face perceived or real borrowing constraints due to imperfect capital markets (e.g. Kuuluvainen and Salo 1991; Lönnstedt and Svensson 2000; Saastamoinen and Pukkala 2001). In the case of perfect capital markets, landowner characteristics, such as investment needs, should not be detectable in harvesting decisions. The presence of imperfect capital market conditions changes the basic properties of economically optimum harvesting decisions substantially. Additionally, the use of forest resources as an additional source of income outside of the economically optimum harvesting decisions may result in significant welfare losses, therefore reducing the overall financial viability of NIPF ownership (Tahvonen et al. 2001; Uusivuori and Kuuluvainen 2001). In addition to negative impacts on landowner welfare, capital market imperfections may also decrease the predictability of NIPF timber supply due to the deviation of actual NIPF harvesting from the economic optimum harvesting decisions (Tahvonen et al. 2001).

In addition to the effects of both market variables (e.g. roundwood prices) and market imperfections (e.g. perceived or real borrowing constraints), the harvesting decisions of NIPF owners may be further constrained by legislation governing the
utilization of forest resources. In their study of optimum rotation models for Norway spruce and Scots pine stands in Finland, Hyytiänen and Tahvonen (2001) concluded that regulations such as minimum requirements for average diameter or tree age could result in significant economic losses, especially in the utilization of mature stands. By increasing the average rotation length, these legal limits may also force a larger percentage of the forest landbase into the production of (large diameter) sawlogs than might be indicated by the sawlog/pulpwood price ratio. This would depress sawlog prices, creating welfare losses for the forest landowner. Possible explanations for the existence of these legal limits are the creation of a large standing stock to ensure no future timber shortages as well as the environmental benefits usually associated with more mature stands.

While the aggregate NIPF timber supply seems to be closely related to market characteristics such as roundwood prices and standing inventories, individual NIPF owners are much more flexible in their harvesting decisions. A unique feature of roundwood production is the forest owner’s ability to suspend production. When current market prices fall below the production costs of roundwood, forest owners can respond by delaying harvesting operations or by reducing the intensity of forest management. This feature, combined with the decreasing dependency on income from timber sales provides NIPF owners with a substantial degree of flexibility when making production decisions. The flexibility of harvesting rates in combination with the low costs associated with a temporary suspension of harvesting activities make this option

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17 In Finland, forest management plans for private lands are not binding.
particularly attractive for NIPF owners with comprehensive property rights (Saastamoinen and Pukkala 2001, Yin and Newman 1999).

Attempts to identify the social dimension of NIPF timber supply have been ambiguous. For example, both Bolkesjø and Baardsen (2002) and Ask and Carlsson (2000) reported that the volume of roundwood supplied from NIPF has remained well below the maximum allowable harvesting rates in many Scandinavian countries. They stated that it is possible, that NIPF owners try to meet their non-timber objectives at the expense of timber production, either by excluding some portion of their estate from harvesting or by introducing harvesting techniques that support non-timber objectives while reducing the overall timber yield. Newman and Wear (1993) found a similar reduction in harvesting levels for NIPF lands in the southeastern United States, when comparing the harvesting behavior of NIPF and industrial forest owners.

In a study of NIPF owners in Sweden, Lönnstedt (1998) found significantly higher harvesting rates for farming NIPF owners than for non-farming NIPF owners. Using stand-specific information as the basis for modeling NIPF behavior he was able to partially attribute these differences in harvesting intensities to the lower than average site productivity of forest lands owned by non-farmers. Dennis (1989) reported similar results for NIPF owners in the northeastern United States, where roundwood prices and standing volume were some of the main determinants of harvesting levels. However, landowner characteristics such as the dependency on forestry income as well as the level of education were also found to be significant.
Studies of Finnish NIPF owners' timber supply behavior have found some effects of forest ownership objectives, although a substantial decrease of timber supply could not be detected (e.g. Ovaskainen and Kuuluvainen 1994; Karppinen 1998a, 1998b; Kuuluvainen et al. 1996). Karppinen (1998) identified four distinct groups of NIPF owners. First, multiobjective owners (representing 39% of the forest land) pursued both timber and non-timber objectives, second, recreationists (15% of the forest land) emphasized non-timber objectives, third, self-employed owners (31% forest land) focused on regular sales income and the employment provided by their forests, and fourth, investors (15% of the forest land) identified economic security and asset motives as their major objectives for NIPF ownership. All these ownership groups ranked the importance of timber objectives differently, with timber objectives being most important for self-employed owners and investors, and less important for multiobjective owners and recreationists. The hypothesis that the timber harvesting behavior of these ownership groups was substantially different was rejected, since harvesting intensities were found to be similar across all four ownership groups. Karppinen (1998) concluded that ownership objectives do not substantially affect the roundwood supply in southern Finland, the area where most of the primary wood processing facilities are located.

However, although it has been argued that currently the effects of forest ownership objectives on NIPF timber supply may be relatively low (Kuuluvainen et al. 1996), two distinct ownership groups, recreationists and multiobjective owners, are beginning to place a high priority on non-timber forest ownership objectives (Young and Reichenbach 1987; Bliss and Martin 1989; Kuuluvainen and Salo 1991; Newman and
Wear 1993; Kuuluvainen et al. 1996; Lönnstedt 1997; Karppinen and Hänninen 2000; Hyttinen 2001; Bolkesjø and Baardsen 2002). This discrepancy between intended and actual behavior may diminish in the future, thus creating the need to integrate forest ownership into models of NIPF timber supply.

The parameters used in existing NIPF timber supply models, as well as parameters that have been identified as being relevant for future model development are summarized in Table 5, providing the framework for the development of the MSTD model.
Table 4. Parameters in timber supply modeling.

<table>
<thead>
<tr>
<th>Economic aspects</th>
<th>Biophysical aspects</th>
<th>Social aspects</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Landowner characteristics</td>
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<tr>
<td><strong>Existing models</strong></td>
<td>roundwood prices</td>
<td>standing timber inventory</td>
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<tr>
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<td>harvesting costs</td>
<td>site productivity</td>
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<td>mill demand</td>
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<td><strong>Future model development</strong></td>
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<td>flexibility of supply decisions</td>
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2.5.2. Implications for Model Development

The framework presented in Figure 2 summarizes the characteristics of existing roundwood market models.

Error!
The spatial resolution of existing models of roundwood supply has usually been very high, with the development progressing from stand-specific optimum rotation models based on the Faustman-formula \textit{(neo-classical economics, biophysical aspects)}, to models integrating \textit{landowner characteristics} into the property-specific estimation of timber supply \citep{gregory1987, bliss1989, dennis1989, hyberg1989, koskela1989, lind1994, loyland1995, karppinen1998, lonnstedt1998, yin1999, bolkesjo2002}. \textit{Forest ownership objectives} have been identified as an important component in roundwood supply modeling; however, attempts to incorporate the effect of forest
ownership objectives on NIPF timber supply have so far failed [hatched area, Figure 2] (Newman and Wear 1993; Kuuluvainen et al. 1996; Kuuluvainen and Tahvonen 1997; Karppinen 1998a, 1998b; Ask and Carlsson 2000; Lönstedt and Svensson 2000; Bolkesjø and Baardsen 2002).

The spatial resolution of roundwood demand models has been low, commonly using data that was aggregated at the regional or national level (Brännlund 1989; Brännlund and Löfgren 1992; Toppinen and Kuuluvainen 1997; Thorsen 1998; Toppinen 1998b; Bergman and Nilson 1999; Ronnila and Toppinen 2000; Kallio 2001). Some models have used more disaggregated data on roundwood demand; however, these model builders did not provide any information on the source of the roundwood (Baardsen 2000; Roos et al. 2001; Nyrud and Bergseng 2002; Nyrud and Baardsen 2003).

The implications for an integrated analysis of the dynamics between the buyers and sellers in the roundwood market becomes apparent in Figure 2. Roundwood supply can be modeled with a high spatial resolution (stand or property level), thus providing disaggregate data outputs [bottom left, Figure 2]. The aggregated data provided by regional or national level roundwood demand models [bottom right, Figure 2] therefore becomes a critical limiting factor for an integrated analysis, resulting in a low spatial resolution of comprehensive roundwood market analyses based on these existing models [bottom centre, Figure 2].
3.0 METHODS

3.1 DATA COLLECTION

The development of an improved modeling approach was based on both empirical data (primary data) and a review of the relevant literature (secondary data).

3.1.1 Primary Source

The analysis of wood procurement patterns is based on data provided by UPM-Kymmene Forest. UPM-Kymmene Forest is responsible for purchase, harvest, and transportation of the roundwood for UPM-Kymmene's processing facilities in southern and central Finland (UPM-Kymmene Forest 2000). The dataset contains spatial fibre flow information for all roundwood procured by UPM-Kymmene Forest during the calendar year 2000. In the year 2000, UPM-Kymmene Forest supplied roundwood to 105 medium to large mills throughout southern and central Finland, of which 31 were owned by the parent company UPM-Kymmene. Mill locations, forestry centres, and the delineations of the timber supply areas are shown in Figure 3.
Figure 3. Forestry centers, mill locations and timber supply areas (from METLA 2000, UPM-Kymmene Forest 2000).
The database also contains information on the total roundwood volume that UPM-Kymmene Forest procured for each mill from the five domestic timber supply areas (Kainuu, Ostrobothnia, Central Finland, South-East Finland, and Western Finland), log imports (mainly from Russia and the Baltic states), or from log storage (timber harvested during previous years and stored at the mill yard). Wood procurement information for six roundwood assortments (spruce, pine, and birch sawlogs; spruce, pine, and birch pulpwood) was available for each of the timber supply areas.

3.1.2 Secondary Sources

The next step in model development was a literature review. First, each timber supply model was classified according to the independent parameters used. There was clearly a progression from purely economic models of timber supply (based on parameters such as standing timber inventories, harvesting costs, and roundwood prices) to models that began to integrate social parameters (mainly landowner characteristics such as household income, occupation, or level of education). Landowner characteristics were commonly used as a proxy for forest ownership objectives, suggesting that the direct integration of ownership objectives into timber supply modelling should be considered (Kuuluvainen et al. 1996, Karppinen 1998b, Young and Reichenbach 1987, Bliss and Martin 1989, Dennis 1989, Kuuluvainen and Salo 1991, Hyberg and Holthausen 1989).
The literature review was used to assess the potential parameters to use in describing forest ownership objectives (e.g. recreation use or employment) since these would be a more appropriate proxy for the social aspects of timber supply. In addition to Finnish studies, the review also drew from the timber supply literature in Sweden, Norway, and parts of the United States. While these parameters are critical to improve supply models, they were not included in the development of the mill-specific timber demand model [MSTD].

3.2 MODEL DEVELOPMENT

Based on the literature review, the parameters initially considered in the analysis were DISTANCE, TRANSPORTATION SYSTEM, LOG TYPE, MILL TYPE, MILL CAPACITY, LOG PRICE, PRICE VOLATILITY, and MILL OWNERSHIP (Brännlund et al. 1985; Martinello 1985; Hultkrantz 1987; Löfgren and Ranneby 1987; Hultkrantz and Aronsson 1989; Bergman and Löfgren 1991; Lind and Söderberg 1994; Leskinen and Kangas 1998; Hecker 2003). “VOLUME PROCURED PER TIMBER SUPPLY AREA” was identified as the appropriate dependent variable for modelling spatial wood procurement patterns. Table 5 summarizes the initially selected parameters and the proxies that were used in cases were the relevant data was not directly available.
Table 5. Parameters and proxies tested in the mill-specific timber supply model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter description</th>
<th>Data or proxies used in MSTD model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>Distance from harvesting site to mill gate</td>
<td>Distance from centroid of timber supply area to mill gate</td>
</tr>
<tr>
<td>Transportation system</td>
<td>Road, rail, or water</td>
<td>Indicator variable for multiple transportation systems being used</td>
</tr>
<tr>
<td>Log type</td>
<td>Pulpwood or sawlogs</td>
<td>UPM data (log dimension and quality)</td>
</tr>
<tr>
<td>Mill type</td>
<td>Classification of a mill based on its main outputs such as pulp, sawnwood, and wood panels</td>
<td>Classification of a mill based on the ratio of sawlogs and pulpwood purchased as inputs</td>
</tr>
<tr>
<td>Mill capacity</td>
<td>Physical processing capacity</td>
<td>Volume of roundwood supplied by UPM-Kymmene forest</td>
</tr>
<tr>
<td>Log price</td>
<td>Market price of different roundwood assortments</td>
<td>UPM data</td>
</tr>
<tr>
<td>Price volatility</td>
<td>Regional variation of roundwood prices</td>
<td>UPM data</td>
</tr>
<tr>
<td>Mill ownership</td>
<td>UPM-Kymmene, Stora-Enso, Metsäliitto, Other</td>
<td>UPM data</td>
</tr>
</tbody>
</table>

The theoretical model can be written as:

\[
VOLUME = a + b \times DISTANCE + c \times TRANSPORTATION\ SYSTEM + d \times LOG\ TYPE + e \times MILL\ TYPE \\
+ f \times MILL\ CAPACITY + g \times LOG\ PRICE + h \times PRICE\ VOLATILITY + i \times MILL\ OWNERSHIP
\]  \[1\]

The MSTD model was developed by conducting a regression analysis on the data provided by UPM-Kymmene. Initially the database contained 643 observations with a cumulative fibre flow of approximately 20.5 million m³. Observations for roundwood procured from imports or from storage were excluded from further analysis since the origin of this timber could not be determined. Roundwood from imports and storage accounted for approximately 32% of the total fibre flow; the regression analysis was based on the remaining fibre flow of approximately 13.9 million m³ (n = 501)
observations). Simultaneously, the relevance of price information was tested using a reduced data set. This reduced dataset contained 179 observations, since prices were only available for three of the five timber supply areas (South East Finland, Central Finland, and Ostrobothnia).

The statistical analysis was conducted using the statistical software SAS, release 8.02. A general linear model [PROC GLM] was fit to the entire dataset using the method of least squares for multiple linear regressions (SAS 2001, Timm 2002). Scatter plots were used to identify the mathematical function best describing the basic relationships between the dependent and independent variables. Different transformations of both the dependent and independent variables were tested. A probability of 0.05 was used as the criterion for variables to remain in the model. The coefficient of multiple determination ($R^2$), mean standard error, and conformance with the assumptions of linear regression, and residual plot analysis were used to refine the model equation.

3.2.1 Parameter Transformation

As mentioned, the theoretical model equation [1] was first tested and refined using the reduced dataset (n = 179 observations), since information on log prices was only available for three of the five timber supply areas. Transformations (logarithmic, reciprocal and square) were tested for the continuous parameters; the most appropriate transformation was selected based on the t – test for normality (Neter et al. 1996) as well
as the values for F and $R^2$. The results of these initial modeling runs are summarized in Table 6.

Table 6. Parameter transformation and elimination – reduced dataset.

<table>
<thead>
<tr>
<th>ID</th>
<th>Model equation</th>
<th>F-Value</th>
<th>$R^2$</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>$V = 77443 - 35 \cdot D + 19478 \cdot T + 58195 \cdot S + 48 \cdot M$</td>
<td>7.13</td>
<td>0.25</td>
<td>- Based on theoretical model; $n = 179$, due to limited availability of price information; Elimination of Mill Ownership (estimate equal to zero)</td>
</tr>
<tr>
<td>(ii)</td>
<td>$\ln(V) = 9.33 - 0.00329 \cdot D + 0.57 \cdot T + 1.69 \cdot S + 1.30 \cdot P + 0.01 \cdot L + 0.76 \cdot MC - 0.00009 \cdot MP - 0.092 \cdot LPV$</td>
<td>11.60</td>
<td>0.35</td>
<td>- Logarithmic transformation of Volume; Improved Normality</td>
</tr>
<tr>
<td>(iii)</td>
<td>$1/V = 0.0002 + 0.00000005 \cdot D - 0.00001 \cdot T - 0.0002 \cdot S - 0.0002 \cdot P - 0.01 \cdot L - 0.0002 \cdot MC$</td>
<td>4.95</td>
<td>0.19</td>
<td>- Reciprocal transformation of Volume; Decreased Normality</td>
</tr>
<tr>
<td>(iv)</td>
<td>$(V)^2 = 35989819884 - 153255966 \cdot D + 5.15 \cdot T + 13472031752 \cdot S + 46591725990 \cdot P - 14523487927 \cdot L - 6420539620 \cdot MC - 9746725. \cdot MP + 95526366 \cdot LPV$</td>
<td>3.15</td>
<td>0.13</td>
<td>- Quadratic transformation of Volume</td>
</tr>
<tr>
<td>(v)</td>
<td>$\ln(V) = 10.88 - 0.47 \cdot \ln(D) + 1.31 \cdot S + 1.61 \cdot P - 1.256 \cdot S + 0.0018 \cdot L + 0.76 \cdot MC$</td>
<td>11.45</td>
<td>0.35</td>
<td>- Logarithmic transformation of Distance</td>
</tr>
<tr>
<td>(vi)</td>
<td>$V = 57204 + 4251814 \cdot 1/D + 79002 \cdot T + 54674 \cdot S + 91360 \cdot P - 33983 \cdot L - 2454 \cdot MC - 3 \cdot MP - 1849 \cdot LPV$</td>
<td>5.84</td>
<td>0.21</td>
<td>- Reciprocal transformation of Distance</td>
</tr>
<tr>
<td>(vii)</td>
<td>$V = 82493 - 0.6856 \cdot (D - 13598) + 39429 \cdot T - 102905 \cdot S + 37859 \cdot P + 44.9 \cdot MP + 1621 \cdot LPV$</td>
<td>6.94</td>
<td>0.26</td>
<td>- Quadratic Transformation of Distance</td>
</tr>
<tr>
<td>(viii)</td>
<td>$\ln(V) = 11.89 - 0.46 \cdot \ln(D) + 1.61 \cdot S + 1.61 \cdot P - 0.11 \cdot LPV$</td>
<td>20.03</td>
<td>0.32</td>
<td>- Elimination of Mean Log Price and Transportation System (not statistically significant at $\alpha = 0.05$)</td>
</tr>
</tbody>
</table>
First, the theoretical model equation [1] was tested without parameter transformations (\{i\}, Table 6). Logarithmic, reciprocal, and quadratic transformations of the dependent variable Volume were then tested (\{ii\} \{iii\} \{iv\}, Table 6). The logarithmic transformation of Volume was retained since it generated the most significant improvement both in terms of normality of the model equation, and of values for F and R² respectively. Based on model equation \{ii\}, logarithmic \{v\}, reciprocal \{vi\}, and quadratic \{vii\} transformations of Distance were then tested. The greatest improvement of normality, F-Value and R² was observed using a logarithmic transformation; therefore equation \{v\} was retained. In a final step \{viii\}, the parameters Mean Log Price and Transportation System were eliminated from the model equation, since both were not significant at the 5\% level (α = 0.05).

In a second step, the theoretical model equation [1] was tested using the full dataset (n=501), thus excluding the parameters Mean Log Price and Log Price Volatility from the onset. The preliminary modeling results for the parameter transformation and elimination are summarized in Table 7.
Table 7. Parameter transformation and elimination – full dataset.

<table>
<thead>
<tr>
<th>ID</th>
<th>Model equation</th>
<th>F-Value</th>
<th>R²</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ix]</td>
<td>Volume = 88339 - 278 * Distance - 13401 * Transportation System + 24995 * Sawmill Size Index - 29923 * Pulpmill Size Index - 39659 * Log Type - 26945 * Mill Type Index + 0.12 Mill Capacity</td>
<td>22.15</td>
<td>0.31</td>
<td>price information was removed from the dataset</td>
</tr>
<tr>
<td>[x]</td>
<td>$\log (\text{Volume}) = 9.19 - 0.002 \times \text{Distance} - 0.38 \times \text{Transportation System} + 1.37 \times \text{Sawmill Size Index} - 0.58 \times \text{Pulpmill Size Index} - 0.58 \times \text{Log Type} + 0.35 \times \text{Mill Capacity Index} + 0.0000016 \times \text{Mill Capacity}$</td>
<td>25.95</td>
<td>0.35</td>
<td>Logarithmic transformation of Volume</td>
</tr>
<tr>
<td>[xi]</td>
<td>$\frac{1}{\text{Volume}} = 0.00036 - 0.000000008 \times \text{Distance} + 0.00005 \times \text{Transportation System} - 0.0002 \times \text{Sawmill Size Index} + 0.00008 \times \text{Pulpmill Size Index} + 0.00002 \times \text{Log Type} - 0.00015 \times \text{Mill Capacity Index}$</td>
<td>7.97</td>
<td>0.14</td>
<td>Reciprocal transformation of Volume</td>
</tr>
<tr>
<td>[xii]</td>
<td>$\text{Volume}^2 = 40443950231 - 149895407 \times \text{Distance} - 604916708 \times \text{Transportation System} - 4262511403 \times \text{Sawmill Size Index} - 13616249389 \times \text{Pulpmill Size Index} - 17336200968 \times \text{Log Type} - 18547949858 \times \text{Mill Type Index} - 61458 \times \text{Mill Capacity}$</td>
<td>11.97</td>
<td>0.20</td>
<td>Quadratic transformation of Volume</td>
</tr>
<tr>
<td>[xiii]</td>
<td>$\log (\text{Volume}) = 10.51 - 0.34 \times \log (\text{Distance}) - 0.61 \times \text{Transportation System} + 1.37 \times \text{Sawmill Size Index} - 0.58 \times \text{Pulpmill Size Index} - 0.59 \times \text{Log Type} + 0.33 \times \text{Mill Capacity Index} + 0.0000016 \times \text{Mill Capacity}$</td>
<td>25.84</td>
<td>0.35</td>
<td>Logarithmic transformation of Distance, retaining the logarithmic transformation from equation [vi]</td>
</tr>
<tr>
<td>[xiv]</td>
<td>$\log (\text{Volume}) = 8.59 - 0.23 \times (1/\text{Distance}) - 0.81 \times \text{Transportation System} + 1.36 \times \text{Sawmill Size Index} - 0.58 \times \text{Pulpmill Size Index} - 0.59 \times \text{Log Type} + 0.31 \times \text{Mill Capacity Index} + 0.0000016 \times \text{Mill Capacity}$</td>
<td>25.34</td>
<td>0.34</td>
<td>Reciprocal transformation of Distance, retaining the logarithmic transformation from equation [vi]</td>
</tr>
<tr>
<td>[xv]</td>
<td>$\log (\text{Volume}) = 8.94 - 0.0000045 \times (\text{Distance}^2 - 0.32 \times \text{Transportation System} + 1.36 \times \text{Sawmill Size Index} - 0.59 \times \text{Pulpmill Size Index} - 0.56 \times \text{Log Type} + 0.36 \times \text{Mill Capacity Index} + 0.0000016 \times \text{Mill Capacity}$</td>
<td>25.42</td>
<td>0.34</td>
<td>Quadratic transformation of Distance, retaining the logarithmic transformation from equation [vi]</td>
</tr>
<tr>
<td>[xvi]</td>
<td>$\log (\text{Volume}) = 5.09 - 0.48 \times \log (\text{Distance}) - 0.58 \times \text{Transportation System} - 0.05 \times \text{Sawmill Size Index} - 0.95 \times \text{Pulpmill Size Index} - 0.94 \times \text{Log Type} - 0.79 \times \text{Mill Type Index} + 0.67 \times \log (\text{Mill Capacity})$</td>
<td>38.69</td>
<td>0.44</td>
<td>Logarithmic transformation of Mill Capacity, retaining equation [ix]</td>
</tr>
<tr>
<td>[xvii]</td>
<td>$\log (\text{Volume}) = 11.66 - 0.44 \times \log (\text{Distance}) - 0.25 \times \text{Transportation System} - 1.39 \times \text{Sawmill Size Index} - 0.94 \times \text{Pulpmill Size Index} - 0.79 \times \text{Log Type} - 0.22 \times \text{Mill Type Index} + 0.67 \times (1/\text{Mill Capacity})$</td>
<td>23.95</td>
<td>0.32</td>
<td>Reciprocal transformation of Mill Capacity, retaining equation [ix]</td>
</tr>
<tr>
<td>[xviii]</td>
<td>$\log (\text{Volume}) = 10.56 - 0.38 \times \log (\text{Distance}) - 0.41 \times \text{Transportation System} - 1.76 \times \text{Sawmill Size Index} - 0.50 \times \text{Pulpmill Size Index} - 0.59 \times \text{Log Type} - 0.57 \times \text{Mill Type Index}$</td>
<td>20.11</td>
<td>0.29</td>
<td>Quadratic transformation of Mill Capacity, retaining equation [ix]</td>
</tr>
<tr>
<td>[xix]</td>
<td>$\log (\text{Volume}) = 6.095 - 0.45 \times \log (\text{Distance}) - 0.61 \times \text{Transportation System} + 0.26 \times \text{Sawmill Size Index} - 0.94 \times \text{Log Type} - 0.80 \times \text{Mill Capacity Index} + 0.56 \times \log (\text{Mill Capacity})$</td>
<td>43.23</td>
<td>0.43</td>
<td>Parameter estimate for Mill Capacity less than 1²</td>
</tr>
<tr>
<td>[xx]</td>
<td>$\log (\text{Volume}) = 7.39 - 0.47 \times \log (\text{Distance}) - 0.68 \times \text{Transportation Type} - 0.97 \times \text{Sawmill Size Index} - 0.94 \times \text{Log Type} - 0.80 \times \text{Mill Type Index} + 0.54 \times \log (\text{Mill Capacity})$</td>
<td>46.13</td>
<td>0.45</td>
<td>Elimination of Pulpmill Size Index (not statistically significant at α = 0.05)</td>
</tr>
</tbody>
</table>
First, the theoretical model equation [1] was tested without parameter transformations (\{ix\}, Table 7). Logarithmic \{x\}, reciprocal \{xi\}, and quadratic \{xii\} transformations of the dependent variable \textit{Volume} were then tested, with logarithmic transformation producing the best results. Retaining the logarithmic transformation of \textit{Volume}, logarithmic \{xiii\}, reciprocal \{xiv\}, and quadratic \{xv\} transformations of the parameter \textit{Distance} were tested as well. Since the logarithmic transformation of \textit{Distance} produced the greatest increase in F-Value and R\(^2\), it was retained for the evaluation of transformations of \textit{Mill Capacity}. Compared to reciprocal \{xvii\} and quadratic \{xviii\} transformation, logarithmic \{xvi\} transformation yielded the best results. Equation \{xvi\} was therefore used as the basis for testing different modeling ranges. The modeling range was restricted stepwise by eliminating all observations below a specified threshold in order to eliminate insubstantial timber flows that can be attributed to roundwood redistributed to avoid stockout situations\(^\text{18}\) (Table 8).

\(^{18}\) Stockouts (running out of roundwood) can have a substantial effect on the financial performance of a mill. For this analysis, it was assumed that the roundwood flows observed in Finland could be assigned to two categories; planned and unplanned supply. The \textit{planned supply} is designed to meet the roundwood demand of a mill. \textit{Unplanned supply} are those roundwood volumes that are redirected to a mill where a stockout is about to occur. It was assumed that the unplanned supply cannot be adequately described using the same parameters as for planned supply. Different threshold volumes were tested to identify planned and unplanned supply, with a volume 800 m\(^3\) having the greatest impact on the significance of the model equation. It was not possible to identify any consistent patterns in the allocation of these roundwood flows below a threshold of 800 m\(^3\).
Table 8. Testing restrictions of the modeling range.

<table>
<thead>
<tr>
<th>ID</th>
<th>Model equation</th>
<th>F-Value</th>
<th>R²</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(xxi)</td>
<td>( \log(\text{Volume}) = 5.1 - 0.57 \times \log(\text{Distance}) - 0.16 \times \text{Transportation Type} - 0.02 \times \text{Sawmill Size Index} - 0.21 \times \log(\text{Log Type}) + 0.65 \times \text{Mill Type Index} + 0.54 \times \log(\text{Mill Capacity}) )</td>
<td>15.35</td>
<td>0.16</td>
<td>• n = 501</td>
</tr>
<tr>
<td></td>
<td>• all observations included</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxii)</td>
<td>( \log(\text{Volume}) = 5.1 - 0.57 \times \log(\text{Distance}) - 0.16 \times \text{Transportation Type} - 0.02 \times \text{Sawmill Size Index} - 0.21 \times \log(\text{Log Type}) + 0.65 \times \text{Mill Type Index} + 0.54 \times \log(\text{Mill Capacity}) )</td>
<td>15.35</td>
<td>0.16</td>
<td>• n = 501</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 100 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxiii)</td>
<td>( \log(\text{Volume}) = 8.85 - 0.59 \times \log(\text{Distance}) - 0.31 \times \text{Transportation Type} - 1.25 \times \text{Sawmill Size Index} - 1.27 \times \log(\text{Log Type}) - 1.07 \times \text{Mill Type Index} + 0.48 \times \log(\text{Mill Capacity}) )</td>
<td>28.34</td>
<td>0.29</td>
<td>• n = 412</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 200 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxiv)</td>
<td>( \log(\text{Volume}) = 8.86 - 0.60 \times \log(\text{Distance}) - 0.42 \times \text{Transportation Type} - 1.10 \times \text{Sawmill Size Index} - 1.40 \times \log(\text{Log Type}) - 1.09 \times \text{Mill Type Index} + 0.49 \times \log(\text{Mill Capacity}) )</td>
<td>32.3</td>
<td>0.34</td>
<td>• n = 391</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 300 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxv)</td>
<td>( \log(\text{Volume}) = 8.59 - 0.62 \times \log(\text{Distance}) - 0.49 \times \text{Transportation Type} - 0.98 \times \text{Sawmill Size Index} - 1.14 \times \log(\text{Log Type}) - 0.90 \times \text{Mill Type Index} + 0.50 \times \log(\text{Mill Capacity}) )</td>
<td>32.9</td>
<td>0.35</td>
<td>• n = 378</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 400 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxvi)</td>
<td>( \log(\text{Volume}) = 8.64 - 0.61 \times \log(\text{Distance}) - 0.32 \times \text{Transportation Type} - 1.07 \times \text{Sawmill Size Index} - 1.11 \times \log(\text{Log Type}) - 0.83 \times \text{Mill Type Index} + 0.50 \times \log(\text{Mill Capacity}) )</td>
<td>35.73</td>
<td>0.37</td>
<td>• n = 369</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 500 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxvii)</td>
<td>( \log(\text{Volume}) = 8.44 - 0.56 \times \log(\text{Distance}) - 0.40 \times \text{Transportation Type} - 0.97 \times \text{Sawmill Size Index} - 1.15 \times \log(\text{Log Type}) - 0.94 \times \text{Mill Type Index} + 0.50 \times \log(\text{Mill Capacity}) )</td>
<td>35.55</td>
<td>0.38</td>
<td>• n = 361</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 600 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxviii)</td>
<td>( \log(\text{Volume}) = 7.7 - 0.50 \times \log(\text{Distance}) - 0.63 \times \text{Transportation Type} - 1.02 \times \text{Sawmill Size Index} - 1.19 \times \log(\text{Log Type}) - 1.04 \times \text{Mill Type Index} + 0.53 \times \log(\text{Mill Capacity}) )</td>
<td>42.84</td>
<td>0.43</td>
<td>• n = 354</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 700 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxix)</td>
<td>( \log(\text{Volume}) = 7.4 - 0.47 \times \log(\text{Distance}) - 0.68 \times \text{Transportation Type} - 0.98 \times \text{Sawmill Size Index} - 0.94 \times \log(\text{Log Type}) - 0.89 \times \text{Mill Type Index} + 0.54 \times \log(\text{Mill Capacity}) )</td>
<td>46.13</td>
<td>0.44</td>
<td>• n = 350</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 800 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxx)</td>
<td>( \log(\text{Volume}) = 7.5 - 0.52 \times \log(\text{Distance}) - 0.66 \times \text{Transportation Type} - 0.95 \times \text{Sawmill Size Index} - 0.82 \times \log(\text{Log Type}) + 0.70 \times \text{Mill Type Index} + 0.55 \times \log(\text{Mill Capacity}) )</td>
<td>47.49</td>
<td>0.45</td>
<td>• n = 346</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 900 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(xxxi)</td>
<td>( \log(\text{Volume}) = 7.57 - 0.53 \times \log(\text{Distance}) - 0.66 \times \text{Transportation Type} - 0.92 \times \text{Sawmill Size Index} - 0.82 \times \log(\text{Log Type}) - 0.73 \times \text{Mill Type Index} + 0.54 \times \log(\text{Mill Capacity}) )</td>
<td>45.61</td>
<td>0.45</td>
<td>• n = 341</td>
</tr>
<tr>
<td></td>
<td>• only observations ( &gt;= 1000 ) m³</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As it can be seen from Table 8, the quality of the model equation (based on F-Value and R²) increases while the number of observations included in the analysis...
decreases (Equations {xxi} to {xxxi}). In this case a delineation excluding all observations of less than 800 m$^3$ (Equation {xxix}) was selected, since it provides a substantial improvement in the quality of the model without excluding a disproportionate number of observations from the analysis. In a final step, equation {xxix} was used to test a range of delineations for *Transportation System*. The delineation used in the calculation of the parameter *Transportation System* refers to the distance from the mill, at which the dominant system of transportation changes (e.g. from truck to train/barge). The results of these delineation tests are summarized in Table 9.

Table 9. Testing parameter delineations for *transportation system*.

<table>
<thead>
<tr>
<th>ID</th>
<th>Model equation</th>
<th>F-Value</th>
<th>$R^2$</th>
<th>Comments</th>
</tr>
</thead>
</table>
| {xxxii} | $\log(\text{Volume}) = 8.09 - 0.59 \times \log(\text{Distance}) - 0.71 \times \text{Transportation Type} - 0.96 \times \text{Sawmill Size Index} - 0.97 \times \log(\text{Type}) - 0.84 \times \text{Mill Type Index} + 0.53 \times \log(\text{Mill Capacity})$ | 45.03   | 0.44  | • $n = 350$  
• Switch of transportation systems at 450 km from mill location |
| {xxxiii} | $\log(\text{Volume}) = 8.07 - 0.59 \times \log(\text{Distance}) - 0.36 \times \text{Transportation Type} - 0.95 \times \text{Sawmill Size Index} - 0.96 \times \log(\text{Type}) - 0.84 \times \text{Mill Type Index} + 0.53 \times \log(\text{Mill Capacity})$ | 44.92   | 0.43  | • $n = 350$  
• Switch of transportation systems at 400 km from mill location |
| {xxxiii} | $\log(\text{Volume}) = 7.39 - 0.47 \times \log(\text{Distance}) - 0.67 \times \text{Transportation Type} - 0.98 \times \text{Sawmill Size Index} - 0.94 \times \log(\text{Type}) - 0.79 \times \text{Mill Type Index} + 0.54 \times \log(\text{Mill Capacity})$ | 46.13   | 0.44  | • $n = 350$  
• Switch of transportation systems at 350 km from mill location |
| {xxxiv} | $\log(\text{Volume}) = 7.44 - 0.48 \times \log(\text{Distance}) - 0.35 \times \text{Transportation Type} - 0.95 \times \text{Sawmill Size Index} - 0.94 \times \log(\text{Type}) - 0.79 \times \text{Mill Type Index} + 0.54 \times \log(\text{Mill Capacity})$ | 45.34   | 0.44  | • $n = 350$  
• Switch of transportation systems at 300 km from mill location |
| {xxxv} | $\log(\text{Volume}) = 7.13 - 0.42 \times \log(\text{Distance}) - 0.47 \times \text{Transportation Type} - 1.01 \times \text{Sawmill Size Index} - 0.94 \times \log(\text{Type}) - 0.80 \times \text{Mill Type Index} + 0.55 \times \log(\text{Mill Capacity})$ | 45.91   | 0.45  | • $n = 350$  
• Switch of transportation systems at 250 km from mill location |
While *Transportation System* is statistically significant at the 5% level, the overall effect of the delineation used in the calculation of the parameter on the quality of the model equation is relatively small (Equation \{xxxii\} to \{xxxv\}). However, based on a comparison of the respective F-Values and $R^2$, the best results were obtained using a delineation of 350 km. This final model equation \{xxxiii\} will be analyzed in more detail in the following chapter.

4.0 RESULTS AND ANALYSIS

4.1 MILL-SPECIFIC TIMBER DEMAND MODEL

4.1.1 Overview

The volume of roundwood that a mill purchases within a particular timber supply area was selected as the dependent variable for the analysis of wood procurement patterns. In the following, the term “volume” will be used for the dependent variable, referring to the cumulative roundwood volume of a particular species and grade that a mill procured from a timber supply area during the reference year 2000. Table 10 summarizes the parameter types (class variable or continuous), as well as the range of values before and after transformations.
Table 10. Parameter type and range of values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type(^9)</th>
<th>Unit</th>
<th>Range (before transformation)</th>
<th>Transformation</th>
<th>Range (after transformation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLUME</td>
<td>continuous</td>
<td>m(^3)</td>
<td>1 - 832 042</td>
<td>logarithmic</td>
<td>0 - 5.92</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>continuous</td>
<td>Km</td>
<td>16 - 566</td>
<td>logarithmic</td>
<td>0 - 2.75</td>
</tr>
<tr>
<td>TRANSPORTATION SYSTEM</td>
<td>indicator</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0;1</td>
</tr>
<tr>
<td>LOG TYPE</td>
<td>indicator</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0;1</td>
</tr>
<tr>
<td>MILL CAPACITY</td>
<td>continuous</td>
<td>m(^3)</td>
<td>16 - 2 186 693</td>
<td>logarithmic</td>
<td>1.2 - 6.34</td>
</tr>
<tr>
<td>MILL TYPE INDEX</td>
<td>continuous</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0 - 1</td>
</tr>
<tr>
<td>SAWMILL SIZE INDEX</td>
<td>indicator</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0;1</td>
</tr>
</tbody>
</table>

\(^9\) Indicator variables are commonly used when integrating qualitative information into regression analysis. A detailed discussion of the use of qualitative variables can be found in Neter et al. (1996)

VOLUME refers to the annual volume of roundwood of a particular species and log type delivered to a mill from a timber supply area. DISTANCE is the distance in kilometres from the centroid of the timber supply area to the mill, TRANSPORTATION SYSTEM is a dummy variable for distances over and under 350 km respectively. LOG TYPE refers to the intended use of the timber as sawlogs or pulpwood; MILL CAPACITY is the annual roundwood consumption of a mill in cubic metres; the MILL TYPE INDEX describes the proportion of sawlogs and pulpwood processed by a particular mill, and the SAWMILL SIZE INDEX is a dummy variable for sawmills with an annual capacity greater than 500 000 m\(^3\).

Table 11 summarizes the modelling results, including parameter estimates, standard errors, and levels of statistical significance. Transportation system, log type, sawmill size index, mill capacity, and mill type index were all found to be statistically significant at the 5% level, with distance, log type, sawmill size index, mill capacity, and the mill type index also being significant at the 1% level.
Table 11. Modelling results.

<table>
<thead>
<tr>
<th>Model component</th>
<th>Estimate</th>
<th>Standard error</th>
<th>Pr &gt;</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>7.38</td>
<td>0.89</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Log (DISTANCE)</td>
<td>-0.47</td>
<td>0.12</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>TRANSPORTATION SYSTEM</td>
<td>-0.68</td>
<td>0.32</td>
<td>0.0384</td>
<td></td>
</tr>
<tr>
<td>LOGTYPE</td>
<td>-0.94</td>
<td>0.22</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Log (MILL CAPACITY)</td>
<td>0.54</td>
<td>0.04</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>MILL TYPE INDEX</td>
<td>-0.80</td>
<td>0.25</td>
<td>0.0018</td>
<td></td>
</tr>
<tr>
<td>SAWMILL SIZE INDEX</td>
<td>-0.98</td>
<td>0.29</td>
<td>0.0009</td>
<td></td>
</tr>
</tbody>
</table>

Based on these parameter estimates the MSTD model equation can be written as:

\[
\log (VOLUME) = 7.38 - 0.47 \times \log (DISTANCE) - 0.68 \times \text{(TRANSPORTATION SYSTEM)}
- 0.94 \times \text{(LOGTYPE)} + 0.54 \times \log \text{(MILL CAPACITY)} - 0.80 \times \text{(MILL TYPE INDEX)}
- 0.98 \times \text{(SAWMILL SIZE INDEX)} + \varepsilon
\] [2]

with \(\varepsilon\) being the residual variance\(^{20}\).

The MSTD model [2] is significant at the 1% level, with an F-Value of 46.13, an R-Square of 0.45, and a Mean Standard Error of 4.54 m\(^3\). Figure 4 shows the residual (observed value – predicted value) plotted against the predicted volume. For a perfectly fitting model the residual would be zero. However, such a perfect fit can not be expected

\(^{20}\) Some variation of the y-variable (volume) could not be explained by the x variables used in this model. The residual variance \(\varepsilon\) accounts for the difference between the observed and the predicted y for each observation.
when analysing highly dynamic economic datasets where many factors cannot be controlled.

Figure 4. Residual plot – MSTD model.

The residual plot (Figure 4) shows an increase in error variance with an increase of the response (predicted volume). This heteroscedasticity is inherent in regressions where the dependent variable follows a distribution in which the variance is functionally related to the mean (Neter et al. 1996). Grouping of the observations is one of the possible causes of heteroscedasticity; for example if larger groups have a lower error variance (Kroch 1998 ). The method of weighted least squares\(^ {21} \) can be used to resolve

\(^{21}\) The method of weighted least squares is based on a generalized multiple regression model. Instead of assigning an equal weight to each observation, individual weights are assigned based on the variance of each individual observation. Therefore, an observation with a large variance receives less weight than an observation with a small variance, assuming that those observations with a small variance contain more information relevant for fitting the regression model (Neter et al. 1996).
the problem of heteroscedasticity by placing more weight on observations with a low variance (Neter et al. 1996, Kroch 1998). When plotting the observed volume over the predicted volume (Figure 5), values coinciding with the 45° line would indicate a perfect fit. The MSTD model produces values that are scattered around this 45° line, indicating that some variation of the observed values remains unexplained by the model.

![Figure 5. Observed volume versus predicted volume.](image)

In general, the results of this model equation should be treated with caution. Plotting the residuals versus the observed volume highlights the bias of the MSTD model (Figure 6).
Observed Volume (log)

Figure 6. Residual versus observed volume.

Figure 6 shows negative residuals for low observed volumes, and positive residuals or high observed volumes. This indicates that the MSTD model is biased towards overestimating low volumes, and underestimating high volumes. This bias should be compensated for when interpreting outputs of the MSTD model.

The seemingly imbalanced structure of roundwood markets in Finland would suggest the existence of market imperfections; however, the majority of studies on the competitiveness of roundwood markets in Finland have rejected this hypothesis (Koskela and Ollikainen 1998; Toppinen 1998a, 1998b; Ronnila and Toppinen 2000; Tili et al. 2001). Therefore it can be assumed that the wood procurement patterns introduced in chapter 4.1 are based on a sufficiently competitive market model.
There are dataset limitations which have to be considered when interpreting the MSTD model introduced in equation [2]. Out of a total volume of 17,988,180 m$^3$ of roundwood procured domestically, 81% (14,624,626 m$^3$) were delivered to the group's own mills. Domestic wood procurement includes roundwood purchased from NIPF owners (77%), company-owned forests (8%) and state-owned forests (2%) (UPM-Kymmene Forest 2000). In addition to the wood procured domestically, approximately 3.2 million m$^3$ of roundwood were imported (13% of total wood consumption of UPM-owned mills).

The data used for developing equation [2] describing wood procurement patterns in Finnish roundwood markets is based on a cross-sectional snapshot, covering approximately 25% of the entire roundwood volume traded in Finland in the year 2000 (for a more detailed description of the dataset refer to section 3.1.1). Despite these limitations, a statistically significant model of spatial wood procurement patterns could be developed. Unless noted differently the following discussion only refers to the wood procurement patterns observed based on this dataset.

When analyzing a market structure where a large number of potential buyers (primary wood processing facilities) compete for a limited resource (domestic timber supply), the *procurement intensity* of an individual mill relative to the location of its main competitors becomes a key factor in assessing the competitive position of this in its input market. *Procurement intensity* in this case is defined as the volume a mill procures within a particular timber supply area.
The map of mill locations and timber supply areas (Figure 1) clearly shows that, while the mills owned by UPM were concentrated in 17 locations in Southeast Finland and Central Finland, UPM-Kymmene Forest also supplied roundwood to numerous other mill locations throughout its wood procurement area.

4.1.2 Parameters

Wood procurement patterns can be described by the relationship of volume and distance. As shown in equation [2] the volume of roundwood procured declines steadily the further away a timber supply area is from the location of the mill. As expected, the majority of the wood is procured relatively close to the mill. Since roundwood is a relatively bulky, low value commodity, transportation costs are one of the main factors in determining the allocation (Binkley 1991). However, the wood procurement patterns observed in Finland were more complex.

Distance is a reasonable approximation of transportation costs as long as only one transportation system is being considered. The transportation systems most commonly used for roundwood are trucking, train transport, and barges/freight ships (e.g. (Roehner 1996)). In their simplest form, transportation costs consist of a fixed component for loading and unloading and a variable charge per kilometer traveled. However, as shown in Table 6, the assumption of one transportation system does not hold true for the roundwood markets in Finland, since a change in the dominant transportation system could be detected. (see also (Västilä and Peolola 1997)).
Being an indicator variable *transportation system* can become either 1 (for distances up to 350 km) or 0 (for distances greater than 350 km). The switching point at 350 km was determined iteratively, starting with a distance of 200 km reported as the switching point between truck and train transport in Germany (Hecker 2003). Based on equation [1] it can be assumed that in Finland the dominant transportation system changes from trucking for distances less than 350 km, to transportation by train and barge for distances greater than 350 km (Figure 7).

![Graph of transportation costs](image)

Figure 7: Fixed and total costs for different transportation systems (from Pearse 1990).

In Finland, the two most common systems for roundwood transportation are trucks and trains. Train transportation is usually considered to be more competitive for long distances, while truck transport is better suited for shorter distances. Figure 7 illustrates that the fixed cost component for train is usually relatively high (FC2), since the wood has to be trucked from the harvesting site to the closest train depot as well as...
from the destination train depot to the mill. These additional handling steps are not necessary for pure truck transport, which generally would have lower fixed costs (FC_i). The costs per cubic meter and kilometer are usually significantly lower for train transport than for trucking. Therefore, the slope of the total cost function for truck transport (TC_i) is steeper than for train transport (TC_2).

Concurrent with other studies of Scandinavian roundwood markets, the log type (sawlog or pulpwood) was also found to have a significant influence on the observed wood procurement patterns. (Toppinen 1998b, Brännlund et al. 1985). The ratio of value to volume becomes one of the key factors in determining the economically feasible maximum transportation distance. In 2000, the weighted average price of sawlogs was 45.62 €/m³, while pulpwood was valued at 16.53 €/m³, on average (METLA 2001). Transportation costs are the same for a cubic meter of sawlogs and a cubic meter of pulpwood. Due to their higher value per cubic meter sawlogs can be transported a longer distance before transportation costs exceed the value of the wood. The volume of pulpwood purchased within a supply district is consistently lower than the volume of sawlogs purchased within the same district. Therefore, compared to a pulpmill a sawmill could justify a substantially larger wood procurement area to acquire any volume of roundwood.

Three parameters describing mill characteristics (mill capacity, mill type index, sawmill size index) were found to be statistically significant. Mill capacity is positively correlated with the volume of roundwood procured within a particular timber supply area.

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22 Log type enters equation [2] with a negative sign. Since log type is equal to 1 for pulpwood, and equal to 0 for sawlogs the output values of the MSTD model will always be lower for pulpwood than for sawlogs.
The parameters distance, transportation system, and log type all have negative signs, thus reducing the volume purchased as the timber supply area expands. Mill Capacity however has a positive sign, which means that the effective wood procurement area increases with mill capacity.

The differing prices of products such as pulp, sawn wood, veneer, oriented strand board, and fibreboard can have a substantial effect on the financial feasibility of long-distance log transport. For manufacturing higher valued products (e.g. veneer), the roundwood transportation costs have only a relatively small effect on the profitability of the manufacturing process; while for low valued products (e.g. pulp), transportation costs are one of the main factors affecting profitability. For this study, information on the main products (e.g. pulp, sawn wood, oriented strand board, fibreboard) of the processing facilities was not available. Therefore, a mill type index was used to classify a mill as a pulpmill or a sawmill. The mill type index is calculated using equation [3].

\[
\text{MILL TYPE INDEX} = \left( \frac{100}{(\text{MILL CAPACITY})} \times (\text{PULPWOOD CAPACITY}) \right) / 100
\]  

[3]

The mill type index is calculated as the processing capacity for pulpwod relative to the total mill capacity (including both pulpwod and sawlogs). Following Equation [3], a mill type index of 0 represents a sawmill, and a mill type index of 1 represents a pulpmill. Although the majority of the roundwood is being purchased by
mills at the extremes of the index, there are some mills that procure a mix of both sawlogs and pulpwood (Figure 8).

![Graph showing wood procurement by mill type index.](image)

**Figure 8.** Total wood procurement by mill type index.

For example, the majority of the pulpwood is being purchased by mills with a Mill Type Index between 0.90 and 0.99; indicating that the sawlog volume purchased ranges from 1-10% of the total volume. This is reasonable, since pulp mills can substitute sawlogs for pulpwood and sometimes do so because of the additional costs of log sorting and transportation that would be incurred if separating out sawlogs during harvesting operations focused on pulpwood. The substitution of sawlogs in the production of pulp and paper can also be expected in situations where no sawmill is located within a reasonable distance from the harvesting site, or when the market price for sawlogs falls below the price of pulpwood. The mill type index of 0 represents mills that process only sawlogs: The volume being purchased by mills with a mill type index between 0.01 and
0.09 is much lower than for mills with a mill type index between 0.90 and 0.99, suggesting that pulpwood is generally not an adequate substitute for sawlogs23 (Nyrud 2002, Størdal and Nyrud 2003, Brännlund 1989).

As with the impact of log type on wood procurement patterns, the effect of the mill type can also be attributed to the relative price differences of pulpwood and sawlogs. The mill type index in equation [2] has a negative sign; therefore, mills with a mill type index close to zero (sawmills) are procuring their roundwood from a larger area than mills with a mill type index close to one (pulpmills).

The sawmill size index is an indicator variable for a combination of mill capacity and mill type index. As an indicator variable, the sawmill size index is assigned a value of 1 for sawmills with an annual sawlog procurement between 50 000 and 500 000 m$^3$; otherwise the sawmill size has a value of 0. The negative sign of the sawmill size index in equation [2] indicates that the purchasing intensity (volume of roundwood procured within a timber supply area) of sawmills with a sawmill size index of 1 is lower that for either smaller or larger sawmills. This indicator variable can be interpreted as a correction factor adjusting the output of the MSTD model to account for the different wood procurement behavior observed for medium-sized sawmills.

In addition to the parameters included in the MSTD model (Equation [2]), Log Price Volatility was identified as being statistically significant at the 5% level when

23 However, there may be some cases were the identification of pulp mills and sawmills based on the volumes of sawlogs and pulpwood they purchase may not be accurate. Especially for relatively small processing facilities it is often possible to occupy a market niche based on the manufacturing of a low value input such as pulpwood into a higher valued output. To address this issue, it would be necessary to account for the actual use of the roundwood in the determination of the mill type index (Equation [2]). This was not possible with the data available for this study.
testing the theoretical model (Equation [1]) with a reduced dataset that also included price information. Log Price Volatility was calculated as the standard deviation of the log prices observed within each timber supply area. It enters the model equation (Table 6 [viii]) with a negative sign, indicating that less roundwood was procured from those areas with unstable log prices. One possible interpretation is a risk avoidance strategy in roundwood procurement, whereas the forest products industry centers its wood procurement strategy on those timber supply areas where the financial risk associated with price variations is minimal.

4.1.3 Improvements and Limitations.

The framework presented in Figure 9 describes the improvements made in the development of the MSTD model compared to existing roundwood market models.
The insufficient resolution of existing models of timber demand [bottom right, Figure 9] has been addressed in the development of the MSTD model. The output of the MSTD model is highly disaggregated, providing spatially explicit information on the source of roundwood for individual processing facilities [top right, Figure 9]. Although the current version of the MSTD model was based on data aggregated at the level of the timber supply area (Figure 5), the model algorithm is sufficiently flexible to accommodate stand level information. The spatial resolution can be increased by adjusting the method for determining the distance between the source of the wood and the mill. Depending on data availability the proxies “volume procured within the timber...
supply area” and “distance from the centroid of the timber supply area to the mill” can be replaced by spatially more explicit data. Limitations of the database did not allow for the integration of roundwood supply in the development of the prototype MSTD model. However, the ability of the MSTD model to accommodate highly disaggregate data makes it possible to integrate models of roundwood supply at the stand level. This stand specific input could integrate all four components (neo-classical economics, biophysical aspects, landowner characteristics, and forest ownership objectives) that have been identified as being relevant for roundwood supply modeling.

It should also be noted that the MSTD model was developed based on a cross-sectional data, capturing approximately 25% of the Finnish roundwood market in the year 2000, accounting only for those roundwood volumes that were handled by UPM-Kymmene Forest. Therefore, the actual parameter estimates provided in equation [2] may not be applicable to other segments of the Finnish roundwood market. Nevertheless, at the current stage of development the MSTD model should be interpreted as a proof of concept rather than a fully operational model. While the framework used for developing the MSTD model aims at enabling a spatially explicit high resolution integrated analysis of roundwood markets, only the roundwood demand side has successfully been integrated in the current version of the MSTD model.
5.0 CONCLUSIONS

There have been concerns about the competitiveness of the Finnish roundwood markets. However, despite the seemingly imbalanced market structure with a large number of sellers interacting with a highly concentrated forest products sector, a competitive market exists. A recent development to ensure a competitive market structure has been the elimination of purchasing cartels and centralized price negotiations that were prevalent until 1999. A weakness in the traditional analysis of market structure has been the use of aggregated data in demand side modeling which lead to very low spatial resolution results when analyzing timber demand and supply simultaneously.

The MSTD model is useful for describing the spatial wood procurement behavior of mills in southern and central Finland based on mill characteristics such as mill capacity and mill type; and, the strong influence of the distance to the harvesting site and the log type (a proxy for the value/weight ratio) emphasizes the role of transportation with its associated costs as one of the main factors determining the allocation of roundwood. The high spatial resolution of the MSTD model allows for the direct integration of NIPF forest ownership objectives. At this stage the limited availability of information on forest ownership objectives as well as discrepancies in the spatial resolution of data on roundwood procurement and forest attributes made it impossible to conduct this integration. Nevertheless, using a model such as MSTD, individual forest owners are able to identify those mills that are most likely to purchase roundwood from their forest property. By inviting offers from all of these mills, the landowner could help ensure that the roundwood harvest is allocated to its most efficient use.
For the forest products industry, the further development of the MSTD model, integrating forest ownership objectives, would help create an improved industrial strategy for increased supply security. It would link the roundwood demand of a processing facility to individual timber supply areas and provide spatially explicit information on the availability and variability of roundwood supply within the timber supply area.

6.0 AREAS FOR FUTURE RESEARCH

In addition to further refinements of the MSTD model based on the existing dataset (for example, re-estimating the model parameters using the method of least squares to compensate for heteroscedasticity), future research could follow three possible directions. First, the level of data aggregation has been a central concern for timber supply models. Most of the earlier studies have relied on data that was aggregated at the regional or even national level, thus severely limiting the possibilities for interpreting these results in the context of usually highly specific local timber markets. While it was possible to develop model of wood procurement behavior based on disaggregated mill-level data, one of the main constraints for this project was the spatial incompatibility of information concerning fibre flows, pricing information, and forest and forest owner characteristics. Therefore, an expansion of the database to include these parameters could substantially improve the accuracy of the MSTD model. Second, the MSTD model was developed based on empirical data capturing approximately 25% of the Finnish roundwood markets in the year 2000. The integration of time series data as well as
information on a larger portion of the Finnish roundwood markets could also improve the fit of the MSTD model. Third, the study results on the impact of non-timber objectives on NIPF timber supply have been inconclusive. Due to the central role that NIPF holdings play for the wood procurement of the forest products sector in Finland further efforts should be made to develop a sound understanding of the effects that non-timber objectives may have on roundwood supply from non-industrial forest lands. The MSTD model can be seen as a first step in developing more advanced mill-specific models [MS-TDS]. Maintaining the high spatial resolution of the prototype MSTD model, these models can then be used to provide compatible timber supply and demand information for an integrated roundwood market analysis (Figure 10).

Figure 10. Framework for future integrated model development.
One possible approach to assessing the of forest owner impacts would be the development of associations between non-timber objectives and particular silvicultural systems, which could provide a method for assessing the potential for harvesting activities while maintaining non-timber values.

The MSTD model can also be used as a framework for the development of similarly comprehensive roundwood market models in other regions with rapidly changing market conditions. For example, the current changes in forest policy in British Columbia could result in a market structure similar to Finland by encouraging smaller scale forest management while maintaining the existing highly concentrated structure of the forest products industry. The associated departure from the annual allowable cut concept for yield regulation would create a need for more flexible approaches to timber supply planning.
7.0 LITERATURE CITED


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