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Draft Manuscript for Review

**Volume yield and profit in the production of clear finger-jointed Scots pine (*Pinus sylvestris* L.) boards**

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Review

# Volume yield and profit in the production of clear finger-jointed Scots pine (*Pinus sylvestris* L.) boards

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## Abstract

The aim of this study was to compare the volume yields and contribution margins in the production of clear finger-jointed boards using lower quality raw materials from four suppliers. The study is based on production statistics from 2005 to 2007 and has been carried out in cooperation with a company which manufactures clear finger-jointed boards for mouldings. The raw material was side-boards of Scots pine (*Pinus sylvestris* L.) with dimensions of 32 by 175 mm<sup>2</sup>. The four raw material suppliers are geographically distributed in different places in Central Sweden. Parallel with the study, a tool for production follow-up has been developed, to make it possible for the company to continuously follow-up its raw material suppliers.

The results of the study show that the cheapest raw material gives the highest clear wood volume yield and the highest contribution margin.

## **Ausbeute und Erlöse bei der Herstellung astfreier, keilgezinkter Kiefernholzbretter (*Pinus sylvestris* L.)**

### **Zusammenfassung**

Ziel dieser Studie war es, die Volumenausbeuten und die Bruttogewinne bei der Herstellung astfreier keilgezinkter Bretter aus Brettern geringerer Qualität von vier Lieferanten zu vergleichen. Die Studie wurde auf Grundlage von Produktionsstatistiken der Jahre 2005 bis 2007 in Zusammenarbeit mit einer Firma durchgeführt, die astfreie keilgezinkte Bretter für Schreinerarbeiten herstellt. Als Rohstoff dienten Seitenbretter aus Kiefernholz (*Pinus sylvestris* L.) mit den Abmessungen 32 x 175 mm<sup>2</sup>. Die vier Rohstofflieferanten stammten aus unterschiedlichen Gegenden in Zentralschweden. Parallel zu dieser Untersuchung wurde ein Programm zur Produktionsverfolgung entwickelt, das der Firma eine kontinuierliche Rückverfolgung der Herkunft der verwendeten Bretter ermöglicht.

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3 Die Untersuchung ergab, dass das billigste Ausgangsmaterial die höchste  
4 Volumenausbeute und den höchsten Bruttogewinn ergab.  
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## 8 Introduction

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11 The manufacture of architraves, skirtings and other mouldings of solid pine wood  
12 makes high demands on the raw materials used. Traditionally, the raw material for  
13 these products has to be of high and uniform quality, sorted in accordance with  
14 standardized quality rules. In the Nordic countries these standardized rules are  
15 generally associated with “The Green” and “The Blue” books (Anon 1982, Anon  
16 1994) and the European standard EN-1611-1 (Anon 2000). Shortages of raw  
17 materials in addition to higher prices for the higher wood qualities have led the  
18 manufacturers of fillets and mouldings to look for an alternative. One possibility  
19 is a knot-free finger-jointed board material.  
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23 To cut wood pieces with acceptable characteristics from a raw material, which  
24 according to the quality rules is of low quality and therefore cheap, followed by  
25 finger jointing into a clear board is one way of adding value to the wood material  
26 (Maness and Wong 2002). In their simulation study, these authors have shown  
27 that the value and the quality of the cut material are influenced not only by the  
28 raw material quality but also by other factors such as the scanner equipment and  
29 the material handling. In the manufacture of a knot-free finger-jointed product, the  
30 raw material constitutes a considerable part of the total cost. According to Zuo et  
31 al. (2003), the quality of the raw material in the cutting has a decisive influence on  
32 the productivity. A raw material of low quality is cheap but more difficult to  
33 process while a raw material of high quality is more expensive but easier to  
34 process.  
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39 The properties of the wood in trees, e.g. annual ring width, distance between  
40 whorls etc., are influenced by genetic and environmental factors and also by  
41 decades of human management. When the log is sawn into boards and planks, the  
42 quality is as a rule changed since the quality rules for the assessment of sawn  
43 timber have been related to the expected quality of the sawn main yield (Nylinder  
44 and Törnmark 1985). It is difficult to make objective comparisons between  
45 today’s quality and that of former times, since the old statistics relating to the  
46 quality of the sawn timber are difficult to interpret. Nylinder and Törnmark (1985)  
47 noted that a change has taken place with respect to wood quality, but they are of  
48 the opinion that this could be due to the method of valuation, and the definition  
49 and interpretation of wood quality. Furthermore, they suggest that the quality of  
50 the raw material from the Swedish forest in the future may change for the worse,  
51 but that this can be compensated for by a better handling of the raw material after  
52 felling. The quality has also changed in North America. This has taken place at  
53 the same time as the availability of first generation forests has decreased (Bowyer  
54 et al. 1986; Pellicane et al. 1987).  
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59 Sandberg and Johansson (2006) have made a comprehensive literature review on  
60 the effect of knottiness on Scots pine and Norway spruce using various  
techniques. They have studied the difference between square- and star-sawing  
patterns on the volume yield during the production of knot-free components from

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sawn boards of Scots pine, and have shown that the sawing pattern has a great influence on the volume yield of knot-free components.

It is generally known that the farther south in Sweden the tree has grown the greater the distance between the branch whorls in the trunk. Sandberg and Holmberg (1996) have shown that the volume yield of knot-free components from star-sawn boards of Scots pine and Norway spruce from different locations in Sweden differ depending on the latitude.

## Objectives

The objectives of this study are:

- to compare the volume yield and contribution margin in the manufacture of clear finger-jointed boards of sawn timber from four selected sawmills in different parts of Central Sweden
- to develop a tool which makes it possible for the company to continuously follow-up its production results and raw material suppliers.

## Materials and methods

The major product of the studied company is a clear finger-jointed board for planed architraves and skirting fillets. In this study, a clear finger-jointed board is a board free from growth characteristics like knots and resin pockets, discolorations and holes, and also from wane, splits and cracks. For the production of clear finger-jointed boards, the company purchases a specific quality of raw material of Scots pine from several sawmills.

### Raw Material

The raw material used in this study was side-boards of Scots pine with a cross sectional dimension of 32 by 175 mm<sup>2</sup> and varying lengths. The basic requirement on the raw material has to be not lower than Grade VI according to the Swedish sawn timber grading rule (Anon 1982). In addition, the moisture content shall be approximately 12 %, and there shall be at least 400 mm between knots and other undesirable defects such as resin pockets and cracks, in order to achieve a favourable production flow.

For this study only four suppliers were chosen. The suppliers are located in the Central part of Sweden. Sawmills A, B and C are located at approximately the same latitude, sawmill A being closest to the Baltic Sea coast and sawmill C being farthest to the west. Mill D is located inland but farther to the south. All four sawmills lie within a radius of 200 km from the studied company.

For the investigation, archive data from January 2005 until December 2007 were used. One of the raw material suppliers (sawmill D) is a supplier only since

December 2006. The selected data from the production statistics comprise a total of slightly more than 5 000 m<sup>3</sup> used in almost 200 runs, Table 1.

Table 1. Summary of the raw material volumes included in the study.

Supplier	Raw material volume [m <sup>3</sup> ]	Proportion [%]	Number of runs
Sawmill A	1953	38.7	73
Sawmill B	550	10.9	26
Sawmill C	2163	42.8	81
Sawmill D	382	7.6	17
Total:	<b>5 048</b>	<b>100.0</b>	<b>197</b>

### Raw Material Price

The raw material price development from all suppliers between January 2005 and December 2007 is presented in Figure 1. Here, the raw material price has been “normalized” to safeguard the company. During the investigated period, the price of sawn wood in general has risen, which can also be seen in the price development of the raw material included in the study. The price level was stable at the level of 100 until the end of 2006 but rose strongly in 2007.

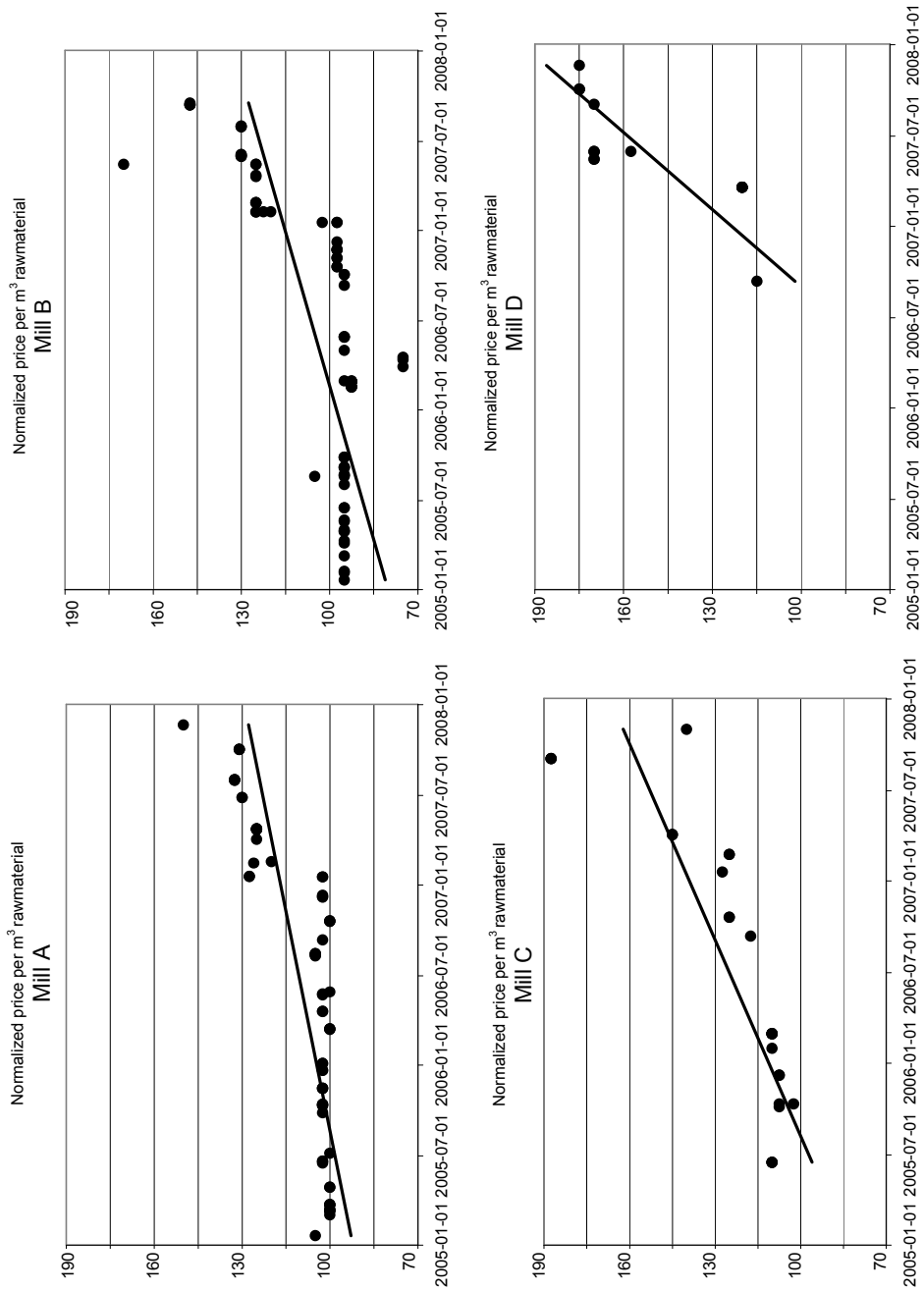


Figure 1. Normalized price development for the raw material 32 by 175 mm<sup>2</sup> from the four suppliers.

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## Clear Board Production

Figure 2 shows a schematic production flow including data collection. The company has used visual scanning technology for a number of years to refine sawn solid wood raw material in an efficient and rational way.

At the intake, the 175 mm wide raw material is split into two approximately equally, i.e., ca. 86 mm wide boards. Then each board is scanned and all necessary data are recorded.

Undesirable features, such as knots, cracks, wane etc, are then cut away from each board using an automatic cutter. The remaining clear wood pieces are finger-jointed, pressed and planed. The primary product of the company is clear finger-jointed boards. However, there are other jointed products like battens where knots are allowed almost without any restrictions. The residuals are used as fuel for heating the company premises or for sale.

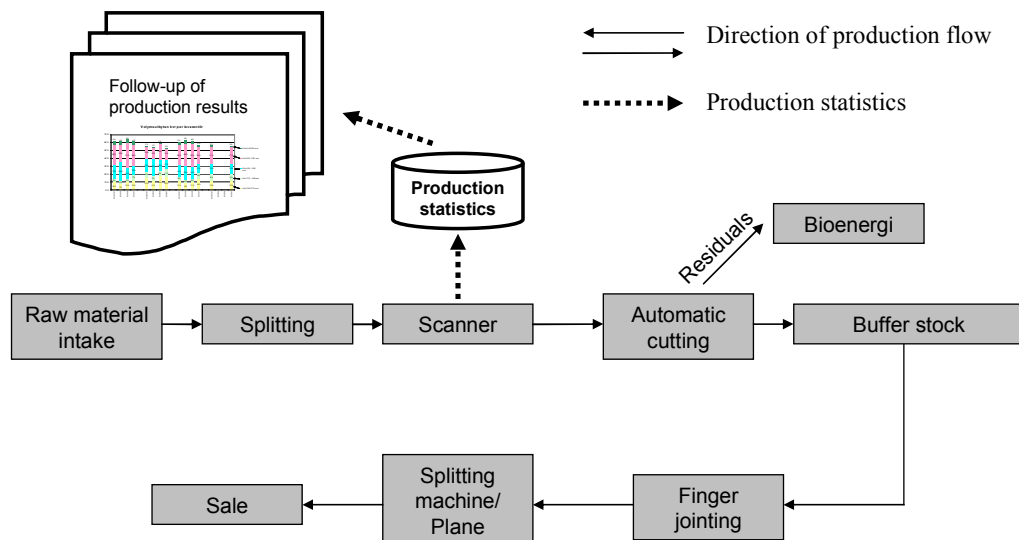


Figure 2. Schematic description of the production flow and storage of the production statistics.

Clear wood pieces are produced by the automatic cutter according to the optimal cutting length information received from the scanner. The clear boards are grouped into four different length classes (230-369, 370-399, 400-549 and 550-750 mm). A clear board with a length of 2220 mm is a specific product and is not finger-jointed, Table 2. Clear board components, longer than 750 mm, but shorter than 2220 mm, are cut into some of these length classes. Clear boards longer than 2220 mm are cut to one 2220 mm board and one or more components in the shorter length classes, provided that the length is sufficient.



Table 2. Description of the sorted and grouped products.

Class	Description	Remarks
A	Clear boards with a fixed length of 2220 mm,	not finger-jointed
B	Clear pieces in falling lengths, interval 550 - 750 mm	finger-jointed
C	Clear pieces in falling lengths, interval 400 - 549 mm	finger-jointed
D	Clear pieces in falling lengths, interval 370 - 399 mm	finger-jointed
E	Clear pieces in falling lengths, interval 230 - 369 mm	finger-jointed
F	Pieces for joining into battens in falling lengths without knot restrictions	finger-jointed
G	Residuals	cut into chips

Generally, in those cases where the scanner identifies a clear board longer than the maximum length of a given class, the optimization function of the scanner will mark for one or several cross-cuts. In the configuration of the scanner, it is possible to guide the optimization towards a desired length component by giving a higher value. In the optimization which is carried out, the placing of the cross cut kerfs is determined by the value set as input data for the calculation of the maximum total value (Åstrand 1996). The mechanical equipment for finger-jointing in the studied company cannot handle boards longer than 750 mm. If a clear board longer than the maximum length of 750 mm is identified, it is divided into two or more lengths, in accordance with a decision which is the result of the optimization process, Figure 3.

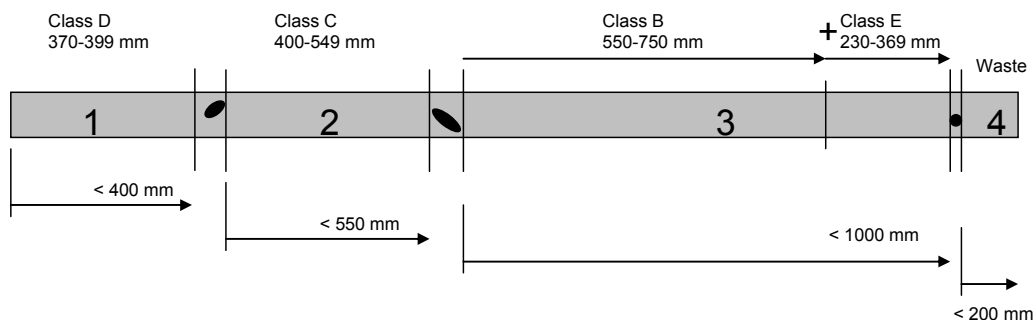


Figure 3. Illustration for cross cut kerfs along a sawn board with four clear board zones.

The division of the wood pieces into length classes which are to be jointed is carried out to meet the most favourable production conditions. However, it is not possible to join components from the longest and the shortest classes at the same time. This means that, in its production, the company buffers components with the longest and/or the shortest length. At the same time, the buffer stock serves to even out the production at a time when e.g. the product dimension is being changed, as well as when the splitting, scanner and cutter equipment are being readjusted.

The split material data generated by the scanner are stored in a database at the end of each shift and also when a raw material supplier and/or product are changed. The scanner statistics consist of the number and total length of components in each class. The data is also supplemented with details concerning the supplier, raw material costs and dimensions, current revenue for each product, production and working time.

## Results

### Volume yield

The cross-sectional dimension used for calculation of volume yields and contribution margins is 32 by 75 mm<sup>2</sup> and is based only on the scanner statistics saved in the database. Therefore, as shown in Table 3, of the total volume of raw material included in the study, 59 % has been refined into clear finger-jointed boards and 8 % into finger-jointed battens and the residual material has been sold for use as fuel.

Table 3. Calculated volume yields of the refined products and residuals

Product	Volume [m <sup>3</sup> ]	Proportion [%]
Clear finger-jointed boards	2979	59
Finger-jointed battens	393	8
Residuals	1676	33
<b>Total:</b>	<b>5048</b>	<b>100</b>

The average volume yield calculated for each supplier for the period as a whole is shown in Figure 4. The distribution of the total volume of clear boards in the different component classes varies between the different mills.

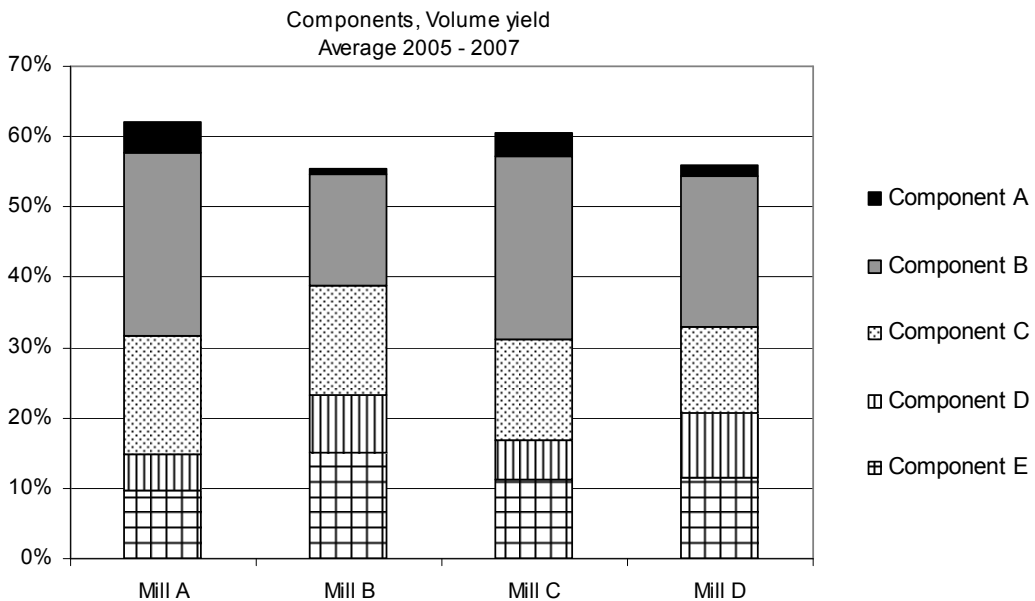


Figure 4. Average total volume yield of clear boards and average distribution of components in different classes per supplier over the whole period.

## Contribution Margin

The Contribution Margin (CM) with respect to wood from each supplier has been calculated as the earnings from the sale, i.e. the Revenue (R), of the produced articles, after deduction of the Variable Costs (VC).

$$CM = R - VC \quad (1)$$

The Revenue (R) at current time for each run will be the same regardless of raw material supplier.

Figure 5 shows the normalized contribution margin per raw material volume of the different suppliers over time. As mentioned earlier the values are normalized to safeguard the host company. Contribution margin per raw material volume makes it possible to compare different suppliers with each other. Such a comparison shows not only a variation between the different suppliers but also that there is a variation between different runs with raw material from the same supplier. A clearly increasing trend can be observed for both sawmill A and sawmill B while sawmill C remains at a constant level. There are only a small number of runs with raw material from sawmill D, but the contribution margin per raw material volume is lower than that of the other suppliers during the corresponding period.

The company has carried out regular reviews of raw material from each supplier with respect to volume yield and the economic result, but, it was not possible to carry out a continuous, systematic analysis and follow-up since no suitable tool has been available.

To make it possible for the company to continuously follow-up the production result and suppliers, a follow-up tool has been developed in this study. This follow-up tool is developed in MS-Excel in order to generate a couple of different diagrams. The tool or the report generator has a direct coupling to the database generated by the scanner, and thus makes it possible for the company to carry out analyses of the ongoing production or directly in connection with a concluded run.

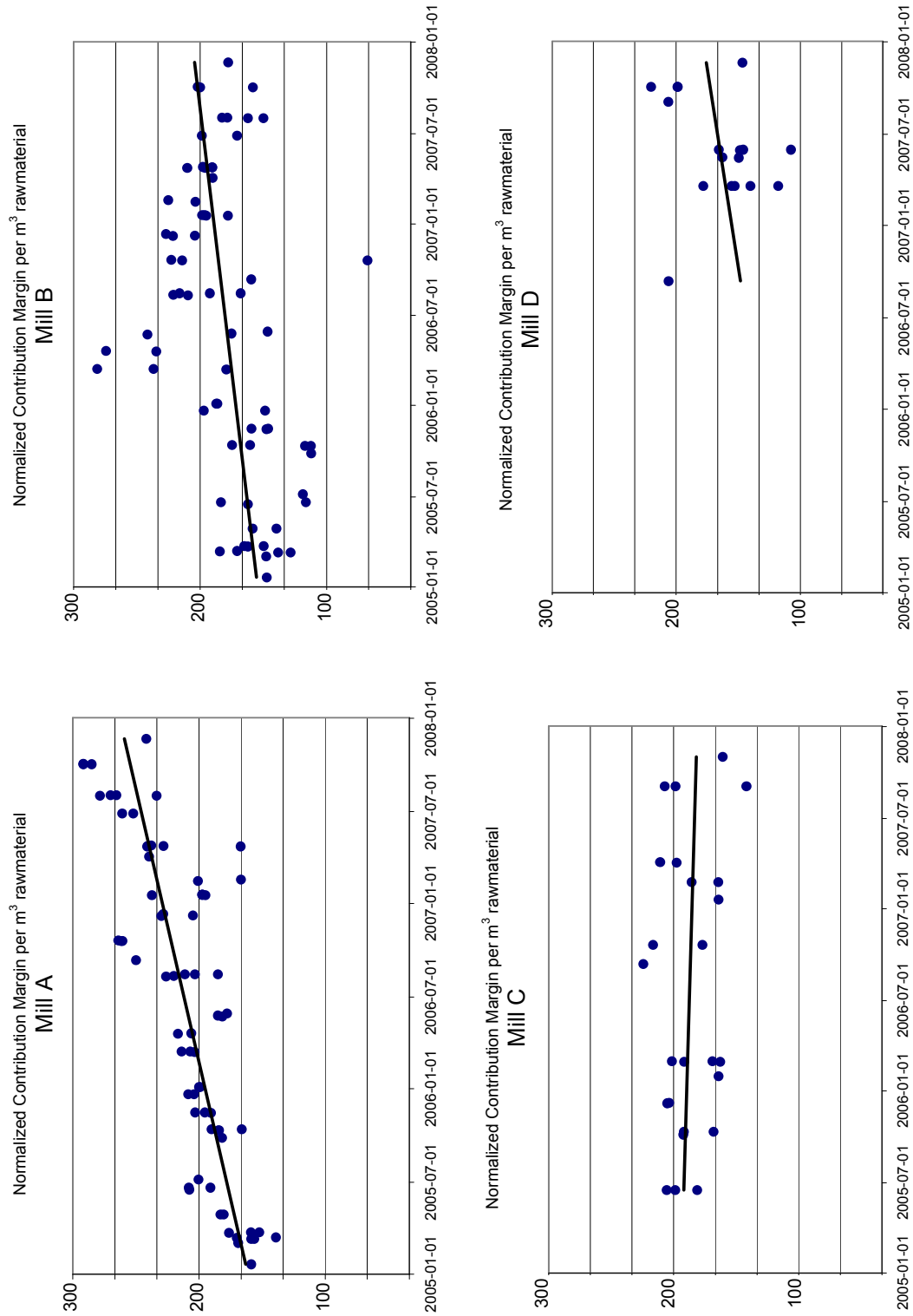


Figure 5. Contribution margin per raw material volume from different sawmills. Values are normalized.

## Discussion

Number of runs shown in Table 1 has to correspond to the number of dots in Figures 1 and 5. However, the same date runs can overlap and will be hard to distinguish.

The company looks for side boards with few knots placed far from each other. Side boards which are sawn from a large diameter log have fewer knots which are placed at a relatively long distance from each other. However, sideboards sawn from small diameter logs are narrower in dimension but have smaller and multiple knots and the whorls are closer to each other.

As the price of the sawn boards does not always fully correspond to the timber quality, a study of this kind is difficult to realize. The difference in raw material price between different suppliers at a given point in time can have several causes, including factors such as long-term agreements which have been made with a supplier or that one supplier does not fully feel the prevailing market price. Another reason can be that a temporary supplier is allowed to deliver a small quantity of raw material practically without any price negotiations. During the period studied, the raw material price has reached levels which the company concerned had not previously experienced. Parallel with the increase in price, the demand for the company's products has also increased and thereby the need for more raw material. The company's experience during the period investigated was that a situation had arisen where there was a shortage of the required raw material. The demands which the company makes on the raw material can be hard for many sawmills to fulfil. The moisture content requirement of 12 %, is one limitation. In addition, the required cross cut dimensions can exclude certain sawmills as suppliers, since relatively large diameter logs are required as input. To establish relationships with new raw material suppliers under these conditions probably means that the price levels will be raised even more.

The fact that the cheapest raw material gives the highest volume yield of clear board can partly be due to the dialogue which the company has carried out with some of its large raw material suppliers. Another contributory factor probably is the geographical origin of the saw timber and the treatment of the sawn article at the sawmill concerned.

During the whole of the studied period, there were relatively large differences in contribution margin per raw material volume between products made from raw material from the various suppliers included in the study. The differences increased during the period and reached a level in the autumn of 2007 where the best raw material gave a contribution margin per raw material volume which was almost 50 % higher than the lowest during the same period. To a certain extent, this can be explained by the fact that the company had been carrying on a dialogue with its most important suppliers for a long time in view of specifying its wishes with regard not only to wood quality but also to other factors such as package design, dirt and oil stains etc. The company feels that the different suppliers vary in their sensitivity to the demands which are put forward.

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The distribution of the components between length classes and the total clear board volume in the respective classes varies with the sawmill supplying the raw material. The differences can be explained by different parameters, of which the geographical origin is probably important, even though this cannot be shown on the basis of this study. The yield is also influenced by the sorting at each sawmill, which in turn is dependent on the price negotiations between the buyer and seller. Two of the sawmills included in the study belong to the same company where the sawn timber is distributed to the two mills according to the top diameter. The top diameter probably also influences the volume yield, since smaller top diameters give logs which come farther from the butt log. In this way, they give a sawn board with properties which differ with respect to the knots.

The proportion of clear component from each supplier varied over the studied period. In addition, there was a difference in the total volume of clear board between different years for the same sawmill. It is probable that the dialogue regarding quality carried on between the company and the different suppliers contributed to this.

The host company has previously carried out follow-ups of its respective suppliers. A supervision of the supplier quality is necessary and it is even more valuable if it can be carried out almost in real time. The dialogue between the company and each supplier has a greater significance if the follow-up is carried out in direct connection with the use of the raw material concerned.

The results of the negotiations relating to raw material purchases influence the quality and price, and these in turn influence the profit contribution. The costs which the company has in form of salaries, maintenance, depreciation, new investments and demands on capital yield must be covered by the profit contribution. For this reason, it is very important to monitor the development of the contribution margin with time, which is one task for which the newly developed evaluation tool can be used.

## Conclusion

In this study, a total volume yield of 59 % has been refined into clear finger-jointed boards.

The results show that the cheapest raw material gives the highest volume yield and the best contribution margin of clear board. Raw material from mill A showed the highest (62 %) volume yield and that from mill B the lowest (55 %). Raw material from both mill A and mill B showed an increasing contribution margin per raw material volume. However, mill C nearly remains at a constant level. The contribution margin per raw material volume using material from mill D was lower than that of the other suppliers during this period.

The study has developed a valuable MS-Excel application to enable the company to continuously follow up its raw material suppliers and also the production results.

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2  
3 Tabelle 1

4 Übersicht über das in dieser Untersuchung einbezogene Ausgangsmaterial

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6  
7 Abb. 1

8 Indexierte Preisentwicklung des Ausgangsmaterials (32x175 mm<sup>2</sup>) der vier  
9 Lieferanten

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11 Abb. 2

12 Schematische Darstellung des Produktionsablaufs und der Speicherung der  
13 Produktionsdaten

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16 Tabelle 2

17 Klassifizierung der Endprodukte

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20 Abb. 3

21 Darstellung der Sägeschnitte in einem Brett mit vier astfreien Bereichen

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23 Tabelle 3

24 Berechnete Volumenausbeuten der zugeschnittenen Produkte und des  
25 Ausschusses

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28 Abb. 4

29 Durchschnittliche Gesamtvolumenausbeute der astfreien Bretter sowie  
30 durchschnittliche Ausbeuten je Klasse (Tabelle 2) und Lieferant im gesamten  
31 untersuchten Zeitraum

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34 Abb. 5

35 Indexierter Bruttogewinn je m<sup>3</sup> Ausgangsmaterial der verschiedenen Sägewerke.  
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