Modelling Future Timber Price Development by Using Expert Judgments and Time Series Analysis

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Leskinen, P. & Kangas, J. 2001. Modelling future timber price development by using expert judgments and time series analysis. Silva Fennica 35(1): 93–102.

Timber prices belong to the most important variables affecting the optimality of forest management. On the other hand, forecasting of timber prices is very uncertain. One difficulty when using past time series data in forecasting future timber price development is the possibility of changes in the markets and in the society at large. Expert knowledge can be applied in forecasting of timber prices as information additional to that provided by time series modelling. This paper presents an approach utilising both time series data and expert judgments in modelling future timber prices. A time series model is used as the basis for the approach. Parameters describing future timber price trends, variation in future timber prices, and the probabilities of price peaks taking place in the future are estimated with expert judgments as the basis. A case study involving 12 experts was carried out in Finland, and models were estimated for all the six major timber assortments in the country. The model produced can be utilised in the optimisation calculations of forest planning.

Keywords expert knowledge, forecasting, forest planning, price peaks, price trend, price variation, uncertainty
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Received 19 October 1999 **Accepted** 12 October 2000

1 Introduction

A good planning process produces information not only on the expected consequences of alternative plans, but also on the uncertainty involved in the decision-making process. In calculations of forest management planning there are several sources of uncertainty. These arise from the development of both economic and biological variables as well as from the social context. Future development of timber prices is affected by both economic and social aspects. Examples of the latter are the processes how price levels are negotiated by sellers and buyers, or by their representatives, and how casewise actual prices are agreed upon in individual deals.

Timber price uncertainty can be taken into account by formulating a stochastic model for timber prices and by simulating price scenarios using that model. The model produces simulated timber price scenarios for the planning period, and these can be used to compute the utility of alternative forest management plans. Utility distributions describing the uncertainty involved in decision alternatives can be derived by repeating the stochastic simulation process several times. Timber price uncertainty can be taken into account in optimisation calculations by utilising these distributions (Pukkala and Kangas 1996).

Earlier, we have shown how timber prices, including price peaks (i.e. the exceptionally high timber prices observed in the early 1950s and mid-1970s) can be modelled for the purposes of tactical forest planning by means of time series analysis (Leskinen and Kangas 1998). Modelling of price peaks is important especially when studying the adaptive behaviour of forestry decision-makers. Kangas et al. (2000) showed how timber price modelling as presented by Leskinen and Kangas (1998) can be integrated with tactical forest planning.

If it is supposed that the variation in future timber prices is similar to that of past price development, the simulation model could be estimated on the basis of past time series data, as in Leskinen and Kangas (1998). Unfortunately, there is no guarantee of this. For example, changes in the social context can have drastic effects on timber price formation. In Finland, the national price agreement system, as applied in the 1980s and early 1990s, has been replaced by less-centralised negotiations between buyers and sellers. As one aim of the national price agreement system was to decrease timber price variation, a question of interest is the size of future timber price variation. Therefore, it is not necessarily optimal to rely on time series data, but attempts are needed to incorporate information external to past history into the simulation model. We should simulate realistic scenarios for future timber prices, not for past development.

The problem can be considered from the econometric perspective, with interest focusing on future supply and demand functions for various timber assortments. Based on supply and demand, future timber prices could then be derived as equilibrium prices (e.g. Gong 1990). However, this requires that the values of the explanatory variables in the supply and demand functions, for example, should be forecasted. For the purposes of tactical forest planning typically applying time horizons of 5 to 20 years, and strategic planning covering 10 to 50 years, this seems to be unnecessarily complicated due to large number of uncertain components in the model.

Webby and O'Connor (1996) reviewed the literature of judgmental and statistical time series forecasting, and concluded that the major contribution of judgmental approaches is the ability to integrate non-time series information into the forecasts. In this study, an approach is presented for constructing a timber price model by utilising both time series modelling and expert judgments. Besides the past development of timber prices, the aim is that also information on the changes in economic and social contexts, as anticipated by human experts, can be considered. The model can be used in tactical forest planning so that the uncertainty in timber price forecasts can be taken into account in optimisation calculations.

The approach is based on the time series model by Leskinen and Kangas (1998). In the approach, expert judgments are used to consider future price trends, variations in future timber prices, and probabilities of price peaks during the next 20 years, these being the central parameters of the time series model. Judgments are made concerning each important timber assortment in Finnish forestry. A case study was carried out in order to test and illustrate the approach, and twelve experts were recruited for the study including participants from the forest industry (buyers), forest landowners (sellers), and researchers.

2 Time Series Model

Leskinen and Kangas (1998) constructed a time series model for logging-year-specific average timber prices in Finland for sawlog and pulpwood of different tree species (Figs. 1 and 2; years 1950–1996). The purpose was to model past timber-price variation, and the model can be used to simulate future timber-price scenarios by assuming that future variation will be similar to that of the past. The observed timber-price varia-

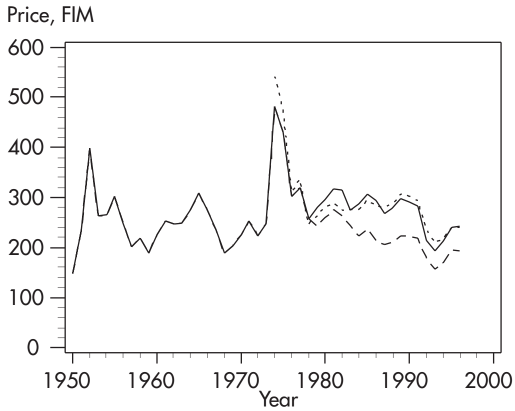

Fig. 1. Real timber prices for sawlog species (index of cost of living, base year 1996). The year 1974, for example, refers to the logging year 1.7.1973–30.6.1974.
Lines: Pine ——, spruce – – –, and birch - - -

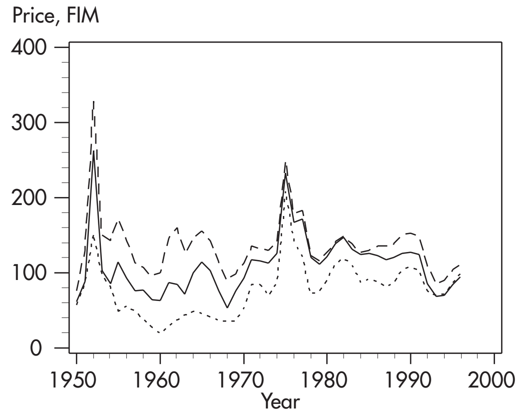

Fig. 2. Real timber prices for pulpwood species (index of cost of living, base year 1996). The year 1974, for example, refers to the logging year 1.7.1973–30.6.1974.
Lines: Pine ——, spruce – – –, and birch - - -

tion was divided into two different processes, one for price peaks, i.e. exceptionally high timber prices observed in the early 1950s and mid-1970s, and the other for the so-called normal price variation, including the rest of timber-price variation.

The identification of a suitable time series model for normal price variation is problematic because of the small number of observations. Leskinen and Kangas (1998) used the AR(1) (autoregressive process of order one) model, which is the simplest reasonable time series model for normal price variation. Let X_t be the logarithmic timber price observed in year t after eliminating the price peaks (see details in Leskinen and Kangas 1998). The AR(1) model is of the form

$$X_t - \bar{X} = \alpha(X_{t-1} - \bar{X}) + Z_t \quad (1)$$

where $\bar{X}$ is the average of X_t (i.e. estimate of population mean) and $Z_t \sim \mathrm{NID}(0, \sigma^2)$, or the variables Z_t are independently and normally distributed random variables with a mean zero and variance σ^2. The AR(1) process is defined to be stationary, i.e. $|\alpha| < 1$. Based on residual diagnostics, the AR(1) model seemed to fit sufficiently well, e.g. no parameter for trend was needed. However, the parameter estimates are rather uncertain because of the small number of observations used. The cross-correlation (e.g. Chatfield 1996) structure of Z_t between different time series was taken into account by using the Cholesky decomposition (e.g. Ripley 1987).

In addition to normal price variation, price peaks were taken as the other part of the observed time series. Due to the small number of observations, the model specification for price peaks is uncertain, but it is better to take into account the features of the observed data, unless there is no reason to believe that the occurrence of price peaks is not possible in the future. Besides, the price peaks can have large impacts on the choice of optimal forest plan.

The occurrence of price peaks was taken as a sequence of independent Bernoulli trials, i.e. a price peak occurs in year t with the probability of p, and it does not occur with the probability of $1 - p$. The effect of price peak V_t on a logarithmic scale was assumed to be of the form $V_t \sim \mathrm{NID}(\mu_V, \sigma_V^2)$. Besides the actual price peaks, it is also possible that the price peak effect could last several years. Leskinen and Kangas (1998) modelled the decreasing effect of price peak at $t = t_0$ with lag i, V_{t0+i}, by

$$V_{t_0+i} = \phi^i V_{t_0} + \eta_{t_0+i}, \quad i = 1, 2, \quad (2)$$

where $0 \leq \phi < 1$, and $\eta_{t0+i} \sim \mathrm{NID}(0, \sigma_\eta^2)$. The empirical estimates of price peak parameters can be found in Leskinen and Kangas (1998). For example, $\hat{\mu}_V = 0.686$.

3 Expert Judgment

The time series model can be used to describe the past timber price variation, but the model does not necessarily produce optimal description of future timber prices. The model is also unreliable in the description of past variation due to the small number of observations. The purpose of expert judgments is to incorporate into the time series model new information that is external to past history.

A questionnaire on future timber prices was sent to the 12 judges. They represented a high level of expertise in Finnish timber price markets, including participants from the fields of research, forest industries, and forest owners' organisations with 4 persons from each of these. One participant from forest industries represented a big forest industry company in Finland, one was from another big company, and one from a medium sized mechanical wood industry company. The first two companies buy and use all the timber assortments considered in the study, and they operate widely in the international markets. The fourth participant from forest industries came from the Finnish Forest Industries Federation. Participants from forest owners' organisations were taken as representatives of timber sellers. One of them was an executive director at a Regional Union of Local Forestry Societies, one was a leader of a Regional Forestry Centre, one came from the Central Union of Agricultural Producers and Forest Owners. The fourth one was a farmer and timber seller involved in many tasks of different forest owners' organisations. The researchers participated in the study came from the Finnish Forest Research Institute (two persons), University of Helsinki, and University of Joensuu.

The experts were asked to present their views concerning the trend in timber prices, the size of timber price variation, and the occurrence of price peaks within the next 20 years (1997–2016). The other components in the simulation model were excluded from the questionnaire; their effects can be considered through sensitivity analyses in practical applications.

The aim of the study was explained in detail to the experts, whose anonymity was also guaranteed. The time series plots shown in Figs. 1 and 2 were given to judges, and the model structure was clarified, especially the separation of the processes for price peaks and normal price variation. The experts were able to present their views about future timber prices freely without any restrictions to pre-determined factors. Also, they had the opportunity to comment concerning the reasoning behind their judgments as well as concerning the approach in general. Special attention was paid to the clarity and simplicity of the questionnaire. Thus, it was not always possible to directly ask about the values of the parameter estimates of the time series model, but more understandable ways were needed (e.g. Kadane et al. 1980).

3.1 Trend

The judges were handed time series plots of timber prices for pine, spruce, and birch sawlogs, and pine, spruce, and birch pulpwoods after eliminating the price peaks and lag-effects. Besides normal price variation, the figures included a line corresponding to the geometric mean of normal price variation over the period 1950–1996. The means for pulpwood species were computed directly from the data, but some changes were made for sawlog species, because pine and spruce sawlogs were not separated in forestry statistics before the year 1979, and because the first available birch sawlog observation was from the year 1974.

The experts were asked to give their estimates as to how the mean timber price (real prices, base year 1996) for each type of timber would change during the period of 1997–2016. The trend alternatives corresponding to 0 %, ±5 %, ±10 %, ±15 %, and ±20 % change of mean timber price within the next 20 years were illustrated graphically for each type of timber. The experts were in a position to choose the alternative best describing his/her opinions, or to give some other percentage change. Fig. 3 refers to +20 % change for pine sawlog, and Fig. 4 to –20 % change for birch pulpwood.

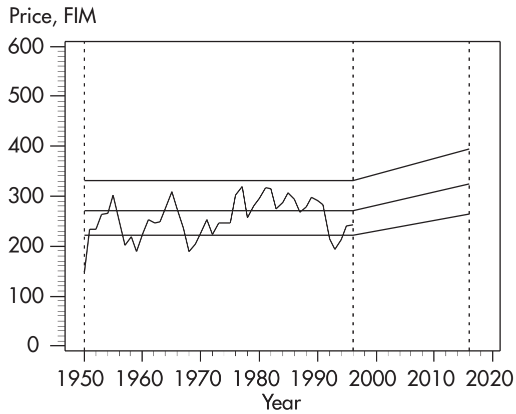

Fig. 3. Real timber prices for pine sawlog after eliminating price peaks, the line of geometric mean, and ±0.2 limits of logarithmic prices in 1950–1996. In years 1997–2016, the geometric mean, and the corresponding upper and lower limits refer to 20 % increase within 20 years.

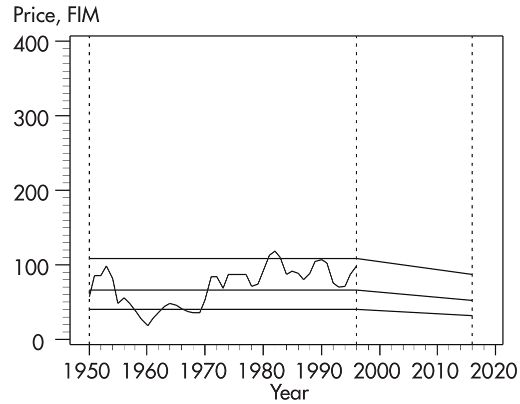

Fig. 4. Real timber prices for birch pulpwood after eliminating price peaks, the line of geometric mean, and ±0.5 limits of logarithmic prices in 1950–1996. In years 1997–2016, the geometric mean, and the corresponding upper and lower limits refer to 20 % decrease within 20 years.

3.2 Timber Price Variation

Besides the geometric mean, upper and lower limits were given to the experts in the form of graphical illustrations such as Figs. 3 and 4. In the case of pine sawlog, for example, the limits were computed so that in logarithmic scale, the mean timber price (i.e. the logarithm of the geometric mean, or the arithmetic mean of logarithmic timber prices) were added and subtracted by 0.2 units; this corresponded to about 40 % width of the "price tube" with respect to the geometric mean. The limits ±0.2 were used also for other sawlog species, as well as for spruce pulpwood. The corresponding limits for pine and birch pulpwood were ±0.3, and ±0.5, respectively. The idea of adjusting the limits was to have a tube covering most of the observed normal price variation, but occasionally these limits were exceeded during the period 1950–1996.

The experts were asked to consider the trend that best describes their opinions as to future timber price development, the corresponding upper and lower limits, and their task was to evaluate the probability that timber prices would stay within these limits in the period of 1997–2016. The upper and lower limits in 1997–2016 associated with the chosen trend were computed as for the period 1950–1996, e.g. a trend ±0.2 limits in the logarithmic scale. The probability of future timber prices staying within these limits were defined to experts so that it equals to 0.9, for example, if 10 % of the future timber prices are outside the limits. Thus, the probability was defined as the average of single probabilities over the 20 years.

The parameter for timber price variation in Equation (1) is the residual variance σ^2, which is computed based on the probability given by the expert as follows. Let X_0 denote the last observed timber price (year 1996), and let $l = 1, 2, ..., 20$ refer to the forecasting period 1997, 1998, ..., 2016. Then, given the data, $E(X_l - \overline{X}) = \alpha^l(X_0 - \overline{X})$, i.e. X_0 has a decreasing effect on the expected value of the AR(1) process. Further, given the data, (e.g. Box et al. 1994, p. 159)

$$\mathrm{Var}(X_l - \overline{X}) = \frac{\sigma^2(1-\alpha^{2l})}{1-\alpha^2} \tag{3}$$

so that also the variance depends on l. Now one can use the estimate of α obtained from the data, the upper limit, the lower limit, the $(X_0 - \overline{X})$, and some σ^2 to compute the corresponding average of single probabilities over the forecasting period, because normality of Z_t implies normality of $X_l - \overline{X}$. If the computed probability is not equal to the probability given by the expert, σ^2 will have to be changed.

The question of the probability that future timber prices will stay within the limits were formulated as the average probability of each of the 20 years, but this is not the only alternative. For example, the probability could have meant ratio of 1's and 0's, were 1 would mean that the timber prices are within the limits in each of the 20 years, and 0 means that the timber price is outside the limits at least in one of the years. The third alternative would be to consider a single year at the end of the forecasting period. Then the calculations can be simplified, because $E(X_l - \overline{X}) \rightarrow 0$, and $Var(X_l - \overline{X}) \rightarrow \sigma^2 / (1 - \alpha^2)$, when l increases. On the other hand, the upper and lower limits could be formulated according to the variance function of Equation (3).

Perhaps more important than the definition of the probability or the formulation of the price limits, a set of reference probabilities were given to experts. Namely, one aim of the question about timber-price variation in the future was to have information about the changes in the Finnish timber-price markets, although it was emphasised to experts that they do not have to concentrate entirely on these changes. However, in 1980s and early 1990s timber prices in Finland were based on a national price-agreement system between representatives of buyers and sellers. Among other things, the system was aimed at decreasing timber-price variation (Simula 1992). There were also agreements before the 1980s, but not to the same extent as in the 1980s and early 1990s. In 1995, the national price-agreement system was changed into regional along the European Union, and since 1997 negotiations have been conducted at the level of individual companies and the representatives of forest owners.

The probabilities associated with upper and lower limits, which lead to residual variance σ^2 estimated from the periods a) 1950–1979, b) 1950–1996, and c) 1980–1991, were given to the experts (Table 1). The probabilities were based on the estimates of α from the entire data (i.e. 1950–1996). Some corrections had to be made for birch sawlog estimates (α, and σ^2) due to lack of observations. Estimation period c) describes the national price-agreement system, and period a) represents a more sparse practice. Estimation period b) includes also the years 1992–1996, when timber prices were formed with or without agreements. Period c) produced the smallest residual variance and the largest probability, period a) had the largest residual variance and smallest probability, and period b) was an intermediate alternative. The idea was not that the expert makes the choice between the three given alternatives, but answers could be given without any restrictions. However, due to Table 1, the experts can evaluate the potential magnitude of the probabilities. Also, it was thought that different interpretations of expressions like "high probability", and "low probability" could become more homogeneous.

Table 1. The probabilities that timber prices are within the price limits with three different estimation periods of the residual variance.

Type of timber	a) 1950–1979	b) 1950–1996	c) 1980–1991
Pine sawlog	0.83	0.86	0.92
Spruce sawlog	0.78	0.82	0.99
Birch sawlog	0.86	0.91	0.9996
Pine pulpwood	0.76	0.81	0.97
Spruce pulpwood	0.75	0.79	0.95
Birch pulpwood	0.67	0.73	0.87

3.3 Occurrence of Price Peaks

The last part of the questionnaire addressed the issue of the probability of future price peaks during the period of 1997–2016. It was emphasised to the experts that the idea was not to forecast the years when price peaks occur, but to evaluate, if the occurrence of exceptionally high timber prices is possible in the future, and what the probability of a price peak in a single year might be. The reference probability was given to experts based on Figs. 1 and 2, i.e. the estimate for price peak probability in year t was 2/47 = 0.043, because two price peaks had occurred (in the early 1950s and mid-1970s) within a period of 47 years.

Table 2. The average results of the questionnaire for trend, probability that timber prices are within the price limits, and the occurrence of price peaks divided into three background categories of the participants. Column "Total" is average of all three categories.

	Type of timber	Research	Industry	Owners	Total
Trend	Pine sawlog	+4.5 %	+5.5 %	+8.8 %	+6.3 %
Trend	Spruce sawlog	+2.0 %	+1.8 %	+4.3 %	+2.7 %
Trend	Birch sawlog	+6.3 %	+8.5 %	+11.3 %	+8.7 %
Trend	Pine pulpwood	–1.8 %	–3.0 %	+3.0 %	–0.6 %
Trend	Spruce pulpwood	+1.3 %	+5.0 %	+6.0 %	+4.1 %
Trend	Birch pulpwood	–1.0 %	–3.8 %	+1.5 %	–1.1 %
Probability	Pine sawlog	0.83	0.82	0.80	0.82
Probability	Spruce sawlog	0.83	0.83	0.80	0.82
Probability	Birch sawlog	0.86	0.84	0.83	0.84
Probability	Pine pulpwood	0.83	0.84	0.83	0.83
Probability	Spruce pulpwood	0.81	0.90	0.83	0.85
Probability	Birch pulpwood	0.85	0.83	0.80	0.83
Peaks		0.05	0.08	0.08	0.07

4 Results

The average percentage change over the 12 experts suggested an increase in mean timber price within the next 20 years for all sawlog species, and for spruce pulpwood (Table 2). In the case of pine and birch pulpwood, the trend seemed to be slightly negative. The average probabilities that timber prices would remain within the price limits varied between 0.82 and 0.85, i.e. the probabilities were practically equal for all types of timber (Table 2). This means that the experts considered future variation to be slightly larger than in the period 1950–1979 in the case of pine and birch sawlogs, and to be the same as the long-run average (i.e. the period 1950–1996) for spruce sawlog (Tables 1 and 2). For all pulpwood species, the results indicated smaller timber-price variation that has been the case in 1950–1996. The residual variances σ^2 corresponding to average probabilities over the 12 experts of timber prices remaining within the limits were 0.016, 0.014, and 0.013 for pine, spruce and birch sawlogs, and 0.024, 0.014, and 0.027 for the pulpwood species, respectively. The average probability of future peaks was 0.07 (Table 2), so that the experts considered the occurrence of future price peaks is possible.

The difference between the parameter estimates obtained from the experts and the estimates obtained from the time series analysis were illustrated graphically in the case of pine sawlog and birch pulpwood (Figs. 5 and 6). Like before, in Fig. 5 the period 1950–1996 refer to zero trend, and the probability that timber prices are within the limits ±0.2 is 0.86 for pine sawlog (Table 1), and in Fig. 6 the corresponding limits and the probability are ±0.5 and 0.73 (Table 1). In the period 1997–2016, the trend is based on the average of all 12 judgments, i.e. +6.3 %, and –1.1 % for pine sawlog and birch pulpwood, respectively (Table 2). The limits for the period 1997–2016 were computed by using the residual variances obtained from the average judgments (i.e. 0.016 and 0.027), and the probabilities from the period 1950–1996 (i.e. 0.86 and 0.73). This leads to limits ±0.22 (Fig. 5), and ±0.41 (Fig. 6). Compared to period 1950–1996, it can be clearly seen that the estimates based on judgment will change the nature of simulated timber price scenarios. This can have significant impacts on forest planning depending on the nature of the case study in question.

The within-group averages were computed in order to compare the impact of the experts' background on the results (Table 2). Because the number of observations in each group was small, the interpretations should be made with caution. However, the representatives of forest owners were positive in that timber prices would be

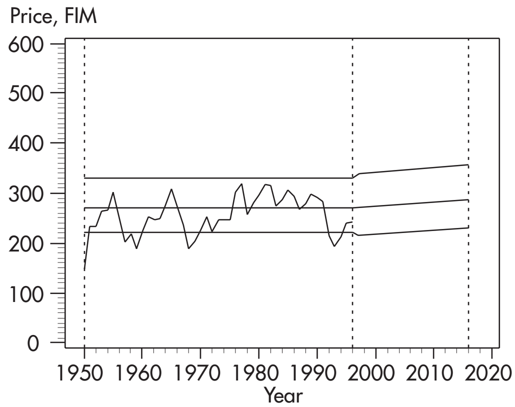

Fig. 5. Real timber prices for pine sawlog after eliminating price peaks, the line of geometric mean, and ±0.2 limits of logarithmic prices in 1950–1996. In years 1997–2016, the limits are computed by ±0.22, and the geometric mean refer to 6.3 % increase.

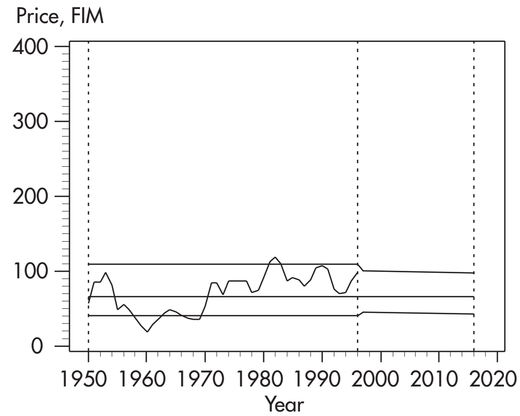

Fig. 6. Real timber prices for birch pulpwood after eliminating price peaks, the line of geometric mean, and ±0.5 limits of logarithmic prices in 1950–1996. In years 1997–2016, the limits are computed by ±0.41, and the geometric mean refer to 1.1 % decrease.

higher in the future, whereas the group of forest industry believed in smaller increase for every type of timber. This indicates that the experts could base their answers partly on their objectives of future timber-price development. On the other hand, the differences between average trends of the industry and the forest owners was not very large. The researchers had smaller absolute values of percentage changes with respect to most types of timber, i.e. they could be considered as being more cautious or conservative in their judgments than industry or forest owners. The average probabilities that timber prices would remain within the limits and the average probabilities of future price peaks were relatively homogenous between the three groups.

According to the results, prices of pine and birch sawlogs were expected to increase while prices of corresponding pulpwood assortments were expected to slightly decrease. Prices of both spruce sawlog and spruce pulpwood were expected to increase so that the expected increase for spruce pulpwood was higher than that for spruce sawlog. According to comments given by the experts, reasoning for these expectations included the following, for instance:

– It is expected that the price of high quality sawlogs is increasing in the world markets, and Finnish sawlogs typically are, internationally compared, of good quality.
– The price of birch sawlog is expected to increase because of the diversification of corresponding end products.
– Tropical hardwood is expected to be a tougher and tougher competitor for birch pulpwood, so the price of it cannot be expected to increase. This partly holds with pine pulpwood as well. However, it is expected that long-fibrous spruce pulpwood will be able to well compete with short-rotation wood material and tropical tree species.
– On grounds of the general structure of forests in Finland, the supply of pulpwood, especially pine pulpwood, is expected to increase while the supply of high quality large trees is expected to decrease.
– In mechanical wood processing industry, that uses mainly sawlogs, the degree of working up will increase.

5 Discussion

The benefits of both time series modelling and expert judgments can be utilised by using the method presented in this study. Time series modelling gives background information on past timber price development and a framework for modelling expert knowledge. The purpose of expert judgments was to incorporate new information external to past history into the time series model.

In Finland, the changes made in the price agreement system a few years ago have caused a situation where assumptions on price processes remaining similar to the observed ones do not necessarily hold. Another potential change affecting future timber prices has been the one taken place in forestry taxation policy. Although the starting point of this study was the actual situation in Finland, the approach in general could be applicable elsewhere, too.

Timber price models for different timber assortments can be used in the optimisation calculations of forest management planning. For example, the models can be integrated with the stochastic planning system presented by Pukkala and Kangas (1996) to study forest management and decision-making under risk and uncertainty as well as the potential benefits of adaptive timber selling behaviour. This can be done in the similar way as the models of Leskinen and Kangas (1998) were applied in optimisation calculations of tactical forestry planning by Kangas et al. (2000).

In the case study, the 12 experts had no opportunity to revise their original judgments. According to the feedback given by the experts, most of them found the questions relatively easy to answer, but some experts had slight difficulties with some of the questions. One potential improvement would be to apply an iterative approach, such as the well-known Delphi technique (e.g. Dalkey and Helmer 1962, Kangas et al. 1998). In Delphi, experts are given feedback from the first questionnaire round concerning both their own and other experts' answers, and they then have an opportunity to revise their judgments. The questionnaire rounds are then repeated several times until the experts' opinions are close enough to each other, or it is clear that the experts no longer change their views. Through the iterations, it is possible to decrease the variation between experts, and to eliminate misunderstandings about the questionnaire.

A potential problem related to the questionnaire might be that the experts give approximately equal probabilities of the timber prices remaining within the given limits for all types of timber. Due to the choice of price limits, this will lead to different development of the size of timber price variation depending on the type of timber. Therefore, it would be beneficial to check if this is what the experts really have meant. Here, Delphi iterations could be used.

A general concern in modelling expertise is the management of the differences between the experts' judgments. Normally, each expert's judgments are given equal weight in the model estimation, i.e. each expert is taken to be equally competent. Another possibility would be to apply different weighting schemes with unequal weighting of experts. The weights could be derived according to, e.g., the level of knowledge each expert represents as determined by the other participating experts, or the level of uncertainty each expert feels his/her answers include. Unequal weighting could also be a remedy to "gambling" of experts. This appeared to be the case in this study, because the representatives of forest owners expected high increase in timber prices compared to the expectations of the opposite side of the timber price markets.

Delphi iterations and weighting of experts are potential ways of improving the approach. Besides, the number of experts could be increased to achieve wider and more reliable description of the views in timber price markets. This would probably require a more simplified questionnaire than the one used in this study. Moreover, in large scale sampling the population of experts should be considered in a different way. For example, a large sample from individual buyers and sellers could be used, but this is not necessarily possible with researchers specialised in timber price markets in Finland. Also, average timber prices concerning the entire Finnish timber markets could be divided regionally, because there are differences in price development between regions.

From the methodological point of view, it would be possible to take into account the variation between experts in forest planning calculations. For example, in a Bayesian framework (e.g. Press 1989) the observed time series could be used as prior information, and a posterior distribution could be formed by using also the expert judgments. In this way, the uncertainty caused by the judgments could be captured instead of merely averaging over experts. This might also be one remedy to the uncertainties caused by the small number of experts.

Acknowledgements

The authors wish to thank Professor Juha M. Alho for his advice during the study, and the 12 experts who kindly responded to the questionnaire. The study has been funded by the Finnish Academy of Sciences, and the Finnish Forest Research Institute.

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