JAPAN'S FORESTS, FORECASTS AND THE FAUSTMANN FORMULA

PETER BLANDON*

ABSTRACT

Japanese forecasting of log output employs a stochastic felling model called gentan probability theory. Usually this theory is applied to those forests thought to be under active management. In this paper the opposite stance is adopted. Forests are divided into two groups, a managed group, the rotation age of which is determined by the Faustmann formula and an unmanaged group which is modelled using gentan probability theory. The proportion of forests in the Faustmann group and the parameters of the gentan probability distribution are estimated using a data set from Aichi Prefecture.

The results show that the proportion of Japan's man-made forests in the Faustmann group has fallen. Also, the mean and variance of the gentan probability distribution have increased, implying that the felling intensity in 'unmanaged' forests is also falling. Reasons for these trends are speculated upon and forecasts for Japanese log output are presented under different assumptions about the proportion of forests under active management.

Keywords: Censored samples, Faustmann formula, Gentan probability, Japan, Log production.

~

INTRODUCTION

Japan is the largest importer of coniferous sawlogs and most of its imports originate from the USA and Russia. It is an increasingly significant importer of coniferous lumber with the bulk coming from the USA, Canada and, recently, Northern Europe. But Japan has a forest cover of two thirds. Nearly 30% of its forests consist of man-made stands of sugi (*Cryptomeria japonica*) and hinoki (*Chamaecyparis obtusa*). In 1997, just over 96% of the output of these forests was used for lumber production.

Almost all man-made forests consist of small stands containing trees of one age and one species. Data concerning age and area are recorded on a stand basis and the age class

* Peter Blandon, Department of Business Studies, London Guildhall University, 84 Moorgate, London EC2M 6SQ, United Kingdom. Email: blandon@compuserve.com. Paper prepared from a presentation given at 150 years of the Faustmann Formula IUFRO symposium at Kranichstein hunting castle Darmstadt, September 1999.

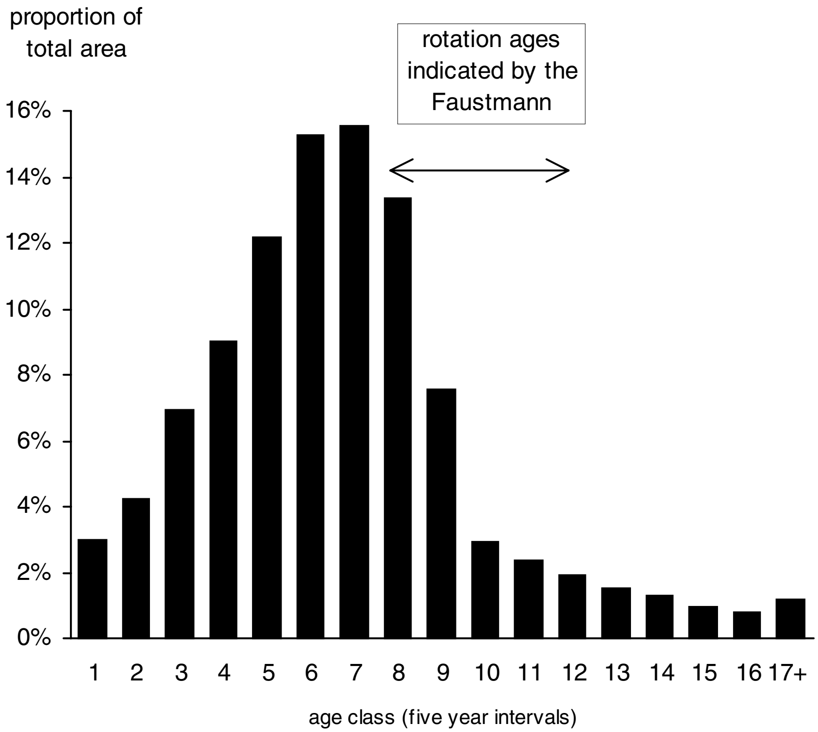
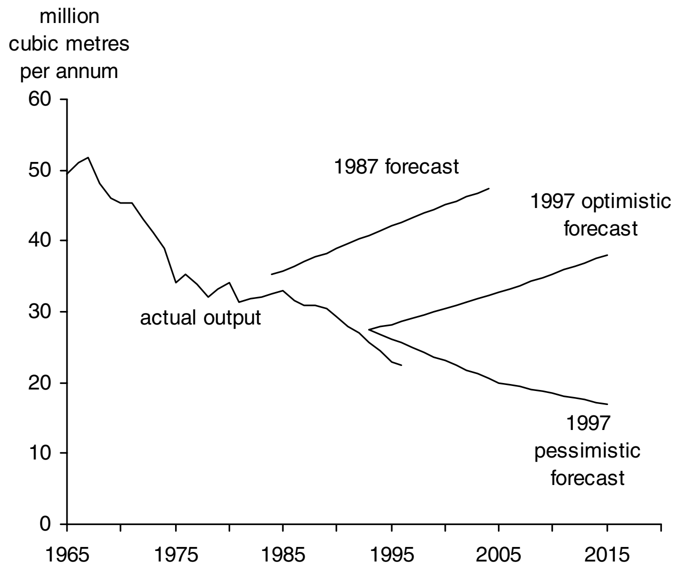


FIGURE 1. THE AGE CLASS STRUCTURE OF MAN-MADE SUGI AND HINOKI FORESTS.

structure of sugi and hinoki forests is shown Figure 1. If 'reasonable' economic values are used in a standard application of the Faustmann formula the results indicate that these forests are rapidly reaching maturity. This has prompted some to talk of a *kokusanzaijidai* or 'era of domestic production'. Were such an era to materialise there would be large implications for the lumber exporters of the West Coast of North America, Russia's Far East and Scandinavia.

Since 1961 the Ministry of Agriculture, Forestry and Fisheries (MAFF) has been required to produce long-term forecasts of demand and supply for the major categories of timber products. The latest version (Shinrin kihon keikaku kenkyuukai, 1997) was based, like its 1987 predecessor, on a mixture of econometrics and simulation with equilibrium in the major product markets being found by manipulating price. The forecasts for the total domestic industrial



Source: *Shinrin Kihon Keikaku Kenkyuukai, 1997.*

FIGURE 2. FORECASTS OF INDUSTRIAL ROUNDWOOD PRODUCTION.

roundwood production are shown in Figure 2. For a fuller discussion of these forecasts in the English language see Blandon (1999).

The 'pessimistic' forecast was produced on the assumption that present trends continue. It is basically an extrapolative forecast. The 'optimistic' forecast, on the other hand, was based on the assumption that government policies such as increased roading and the encouragement of the utilisation of thinnings are successfully implemented. For example, the predicted effect of the roading policy is to raise the proportion of Japan's forests under active management from the presently assumed figure of 40% to around 58%. In the pessimistic forecast this figure falls to 30% by the year 2015 (Shinrin kihon keikaku kenkyuukai, 1997).

The purpose of this paper is first to examine the method used to predict the level of domestic production. The estimates of the proportion of Japan's forests under active management are then questioned and different figures produced using a combination of the Faustmann formula and censored sample theory. The importance of these estimates to forecasts of domestic production is then discussed.

TABLE 1. THE STANDING AREAS AND AREA FELLED OF HINOKI.

Age	Standing Area		Area Felled (F_j)
Class (j)	1987 ($S_{1,j}$)	1992 ($S_{2,j}$)	1987 to 1991
4	1,693	1,287	17
5	1,760	1,676	0*
6	2,241	1,763	8
7	1,623	2,233	10
8	517	1,613	3
9	548	513	4
10	560	544	16
11	782	543	12
12	617	771	33
13	690	584	16
14	447	674	
15+	1,040	1,436	51*

All area figures are in hectares * see text.

THE JAPANESE DOMESTIC SUPPLY MODEL

Although the Faustmann formula is well known in Japan, it was not used in the production of the forecasts shown in Figure 2. Rather the forecasting method developed by Suzuki (1965, 1972, and 1973) and known as *gentan* probability theory was employed.

Gentan Probability Theory

The situation faced by the Japanese in forecasting domestic output is typified by the data shown in Table 1. The table contains figures for hinoki from the Hokusetsu planning area in Aichi Prefecture in central Japan. The data for the standing areas are taken from rolling five-year surveys undertaken by local forestry offices. The felled areas are calculated using Equation 1.

$$F_j = S_{1,j} - S_{2,j+1} \quad \text{for } j = 4 \text{ to } 13. \tag{1}$$

Because the area in age class 15+ is not disaggregated it is not possible to calculate the felled areas for age classes 14 and 15+. All that can be said is that 51 hectares in age classes 14 and above (447+1,040–1,436) were felled. Another problem associated with using such data is the error associated with calculating the felled areas. For example, F_5 is entered in Table 1 as zero, Equation 1 indicating that *minus* three hectares were felled. There appears to be no easy way around this problem.

One impression from Table 1 is the wide range of felling ages, something that cannot be replicated using the Faustmann formula (Blandon, 1991a). In other countries researchers have tackled this issue directly and employed techniques such as Logit or Probit analysis to relate felling probabilities to economic variables and owners' characteristics. However, Suzuki followed a different path. He built a stochastic growth model which, he argued, would lead to a distribution of rotation lengths that he called the *gentan* probability distribution.

The gentan probability, g_j, represents the probability that a forest, planted now, will be felled when it is in age class j. From this gentan probability distribution, a conditional felling probability, f_j, may be derived that expresses the probability that a stand of trees which has survived to age class j will be felled in the current period. This is given by Equation 2.

$$f_j = \frac{g_j}{1 - g_1 - g_2 - \cdots - g_{j-1}}. \tag{2}$$

The forecasting process is now seemingly straightforward. If the parameters of the gentan probability distribution are estimated, the felling probabilities may be derived and forecasts of the areas to be felled estimated by Equation 3.

$$\hat{F}_j = S_{1,j} \hat{f}_j. \tag{3}$$

Suzuki chose the gamma distribution, defined along with its mean and variance in Equation 4 below, to describe the gentan probability distribution. His argument was that diameter growth was a Poisson process with increments occurring in bursts if 1 millimetre (or 1 centimetre in some versions) with the average diameter increment being m millimetres in a five-year period. When diameter reached M millimetres felling would occur.

$$g_j = \int_{t=j-1}^{t=j} \frac{m^M t^{M-1} e^{-mt}}{\Gamma(M)} dt, \quad \mu = \frac{M}{m}, \quad \sigma^2 = \frac{M}{m^2}. \tag{4}$$

To the writer's knowledge, no work has been undertaken to develop the growth model. Indeed, the examples chosen in the Japanese texts do not really suggest that it was to be taken too seriously and in MAFF's models it was not mentioned. In MAFF's forecasting exercises the parameters of the gentan probability distribution have been extrapolated from past trends.

Suzuki seems to have believed that these forecasting applications of his ideas were not of prime importance for he emphasised a Markov chain development of the model. Given a gentan probability distribution that is stable through time, f_j and $1 - f_j$ will be constant. These probabilities are transition probabilities in a Markov chain. They represent the probability that an area of forest moves to age class one, assuming replanting, or age class $j + 1$. This Markov process is such that, no matter what the initial age class distribution in a region, a stable age class structure will evolve dependent only on the parameters of the gentan probability distribution. This, Suzuki argued, was a redefinition of the concept of a normal forest.

Problems with the Forecasting Method

This emphasis on the long run aspects of the model meant that a problem in the derivation of the parameters of the gentan probability distribution was overlooked. Suzuki proposed a method of moments whereby the mean and variance of the underlying gentan probability distribution were estimated by the mean and variance of the *ages of the trees actually felled*. This remains the official procedure in local forestry offices (*Shinrin keikaku seido kenkyuukai* 1992). Equation 5 shows the formula to estimate the mean. This gives a figure of 11.2 age classes for the data in Table 1 assuming that 51 hectares are felled in age class 15. The variance, calculated in a similar way, is 12.8.

$$\hat{\mu} = \frac{\sum_{j=1}^{j=n} jF_j}{\sum_{j=1}^{j=n} F_j} \tag{5}$$

In practice, data for the stands actually felled are obtained by surveys of forest owners at five-year intervals. This means that the errors introduced by using data for standing areas such as those in Table 1 are avoided. The results of these surveys suggested that the mean of the gentan probability distribution was around 50 years, or ten age classes, with a variance of eleven age classes. The figures for national forests were twelve and six respectively. The optimistic forecasts in Figure 2 were based on the assumption that this mean would rise by one age class over the twenty-year forecasting period and the variance by about three age classes (*Shinrin kihon keikaku kenkyuukai,* 1997).

However, as Blandon (1991b) has pointed out, this method of calculation is only approriate if the forest is in the Markovian normal form outlined above. At other times, Equation 5 leads to errors. Put simply, if all the stands in an area are in age class one but are being managed so that the mean of the gentan probability distribution is, say, ten age classes, most stands are destined to be felled in 50 years' time. However, if one tree is felled in the present year, Equation 5 will give a mean of one age class (and a variance of zero). The average age of the trees which are felled is not the same as the average age at which all trees will be felled.

In the post-war circumstances of Japanese forestry, where the bulk of the growing stock is relatively young, the effect of this error has been to produce under-estimates of the gentan probability distribution's parameters. This, in turn, has caused over-estimates in the felling probabilities in the important early age classes. The result has been that forecasts of output using Equation 3 are much higher than actual outcomes.

The response to these over-estimates was the introduction of the idea of a *gentan group*, the group of forests under active management to which gentan probability theory could, legitimately, be applied. The *non-gentan group* contained those forests no longer under active management. The output from them was modelled as a simple random process. For the gentan group the forecasting equation used was that shown below.

$$\hat{F}_j = \lambda_j S_{1,j} \hat{f}_j. \tag{6}$$

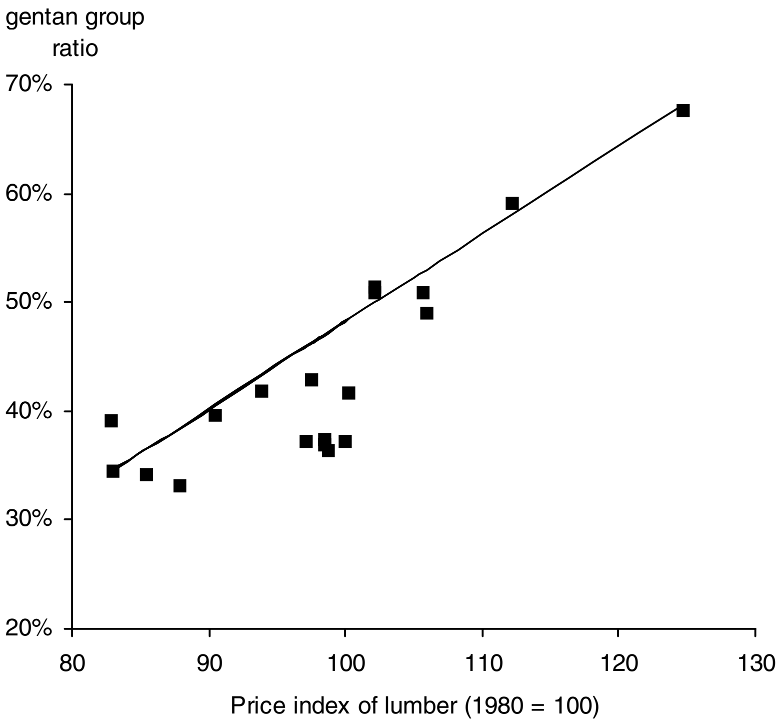


FIGURE 3. THE GENTAN GROUP RATIO IN MAFF'S MODELS.

The variable λ represents the gentan group ratio, the proportion of the total area of forest which is under active management. It was argued that the gentan group ratio was related to such variables as the price of timber and the roading density, these factors determining the extensive margin of forestry. One form of the relationship, from the 1987 forecasting exercise, related the ratio to the price index for domestic industrial roundwood. This is shown in Figure 3 with data for the estimated gentan group ratios from the 1997 forecasts added. The relationship represented by the straight line has not been re-estimated using the new data (*Shinrin keikaku kenkyuukai,* 1987; *Shinrin kihon keikaku kenkyuukai,* 1997).

CENSORED SAMPLE THEORY

The correct method to use in calculating the parameters of the gentan probability distribution was first proposed by Tanaka (1979) and developed by Blandon (1991b). It uses a censored sample approach. To employ this method the data in Table 1 must first be transformed in the way shown in Table 2.

TABLE 2. THE DATA FOR THE MAXIMUM LIKELIHOOD ESTIMATION PROCEDURE.

Age Class j	Survival Ratio $1 - f_j$	Reverse Cumulative Gentan Probability r_j	Estimated Gentan Probability g_j
3	1.0	1.0	0.0
4	0.9900	0.9900	0.0100
5	1.0000	0.9900	0.0000
6	0.9966	0.9867	0.0033
7	0.9941	0.9808	0.0058
8	0.9935	0.9744	0.0064
9	0.9922	0.9669	0.0076
10	0.9710	0.9388	0.0281
11	0.9848	0.9245	0.0143
12	0.9461	0.8746	0.0499
13	0.9773	0.8548	0.0198
		Total	0.1452

The first column in the table gives an estimate of the survival ratio and is calculated by $1 - F_j / S_{1,j}$. This survival ratio may also be defined by Equation 7 which derives from Equation 2.

$$1 - f_j = \frac{1 - g_1 - \cdots - g_j}{1 - g_1 - \cdots - g_{j-1}} = \frac{r_j}{r_{j-1}}. \tag{7}$$

Equation 7 is the reverse cumulative gentan probability for age class j, r_j, divided by that for age class $j-1$. Because of inaccuracies in the data, the assumption is made that no trees are felled in age classes one to three so that $r_1 = r_2 = r_3 = 1$. The subsequent reverse cumulative gentan probabilities can then be estimated from the felling probabilities derived from the data by using Equation 8 which derives from Equation 7.

$$\hat{r}_j = \hat{r}_{j-1}\left(1 - \hat{f}_j\right). \tag{8}$$

From these figures, estimates of the gentan probabilities may be calculated by differencing the reverse cumulative probabilities. Again, it should be observed that the inaccuracies in the data in Table 1 mean that the estimated gentan probability for age class 5 is zero.

The sum of these estimated gentan probabilities is only 0.1452 rather than one. The reason is, of course, that many of the stands are yet to be felled and so an estimate of their felling ages cannot be had. It is this feature of the data which requires the use of censored sample theory. Using the gamma distribution as the model of the underlying gentan probability distribution, the problem becomes one of maximising the log likelihood function shown in Equation 9 with respect to *m* and *M* where *c* is the degree of censoring. In this case, *c* will be 0.8548 or 1 − 0.1452. This is a high degree of censoring and means that the parameter estimates are likely to be unreliable.

$$LL = \sum_{j=1}^{j=13} \hat{g}_j \ln \int_{j-1}^{j} \frac{m^M t^{M-1} e^{-mt}}{\Gamma(M)} dt + c \ln \int_{13}^{\infty} \frac{m^M t^{M-1} e^{-mt}}{\Gamma(M)} dt. \qquad (9)$$

If this method is applied to the data in Table 2 the results are very different. Instead of mean and variance of 11.2 and 12.8 age classes, the results are 22.5 and 97.9 age classes respectively ($\hat{m}$ is 0.23 and $\hat{M}$ is 5.18 which refutes the stochastic diameter growth model). The high average felling age, 112.5 years, implies that many owners are not managing their forests, which here would mean that their felling age would effectively become infinite.

Forests under Management

More importantly, these estimates of the parameters of the gentan probability distribution, when used as a basis for forecasting, produce much more accurate forecasts. Furthermore, any inaccuracies can be explained by movements of the parameters of the gentan probability distribution. If attempts are made to introduce the idea of a gentan group by calculating the survival ratios in Table 2 using formulations such as $1 - F_j / \lambda S_{1,j}$ there seems to be no improvement in the likelihoods returned by Equation 9 and no greater accuracy in the forecasts (Blandon, 1993). So the derivation of the gentan group ratio in the Japanese forecasts is, itself, called into question.

THE PROPOSED APPROACH

The idea of dividing forests into managed and unmanaged forests itself poses a problem. It implies that the overall distribution of felling ages will be a mixture of the distribution for forests under management and that describing forests which are not managed. This would suggest a bi-modal gentan probability distribution meaning that the uni-modal gamma distribution in Equation 3 would be inappropriate.

Furthermore, it seems inappropriate to describe those forests being actively managed by means of what is basically a stochastic process. If coniferous stands are under active management the felling age should be more or less defined by a Faustmann-style approach, provided that markets are fairly efficient. Forests not under active management might be felled when the owner dies and the forest changes hands or when the owner is in need of money and cannot obtain it from the capital markets. This process is far closer to a stochastic one and could feasibly be modelled by gentan probability theory.

So, unlike the Japanese approach, it would seem more reasonable to argue that the forests not under active management can be modelled by the random, gentan process whilst those under active management should be modelled using a non-stochastic Faustmann formula. Adopting this approach means that some of the area felled in a region will come from the Faustmann group and some from the redefined gentan group. Given the absence of any other information, it is necessary, therefore, to derive a Faustmann group ratio, and the mean and variance of the gentan probability distribution from data such as those in Table 1.

To this end, the following approach was adopted. First, a range of 'reasonable' Faustmann-based rotations was derived. Then, assumptions were made about the distribution of the forests in the Faustmann group which enabled the data in Table 2 to be reworked. Finally, the reworked data were used in Equation 9 to determine the variables in question.

The Faustmann-based Rotations

To determine the Faustmann-based rotations data for the growth of sugi and hinoki in Aichi prefecture were used. Work patterns came from Kurimura (1980) and costs from Forestry White Papers. Most of these factors were straightforward but a feature that differs from that in other countries was the nature of the price-size relationship. Sugi's price-size curve appears to be bi-modal. The price per cubic metre first peaks for logs with a top-diameter of around 18cms, then falls off in the 20 to 30cms range only to increase again once the top-diameter exceeds 30cms (Sakaguchi, 1983; Fujimori, 1985). A similar pattern applies to hinoki (Ishihara, 1980; Kurokawa, 1990).

The importance of the market for 10.5cms and 12cms pillars used in Japanese-style, post and beam construction causes this pattern. Once a tree is large enough to yield a pillar its value rises. If it exceeds this size, the wood trimmed off in the production of the squares is of little value and so the log's unit price falls. When the tree is big enough to enter the market for large-sized timber the unit price starts to rise again.

The diameter distribution in a stand will smooth out the log price-size curve somewhat. However, evidence suggests that the distribution of diameters is sufficiently narrow for such a price-size relationship to translate into a dip in the value of the stand on a per hectare basis for certain ages (Iehara, 1989; Kurokawa, 1990).

This price-size relationship was combined with different yield and cost conditions to calculate the Faustmann-based rotations. The result was a range of possible rotation lengths from age class 7 to 12, with rotations between age classes 8 and 11 the most common. The price-size curve showed up with rotations in age class nine being somewhat under-represented. The analysis showed no real difference in the rotation ages for hinoki and sugi. The distribution of rotation ages finally decided upon is shown in Table 3.

TABLE 3. THE DISTRIBUTION OF ROTATION LENGTHS.

Rotation Length (Age Class)	Proportion of Managed Forest
8	25%
9	15%
10	40%
11	20%

Table 4. The Reworked Data (Assuming a Faustmann Group Ratio of 5%).

		Standing Area		Felled Area		
Age Class	Total	Faustmann Group	Gentan Group	Faustmann Group	Gentan Group	Gentan Probabilities
1	621	31	590	0	0	0.0000
2	965	48	916	0	0	0.0000
3	1,285	64	1,221	0	0	0.0000
4	1,693	85	1,608	0	17	0.0105
5	1,760	88	1,672	0	0	0.0000
6	2,241	112	2,129	0	8	0.0035
7	1,623	81	1,541	0	10	0.0061
8	517	26	491	6	0*	0.0000
9	548	21	528	4	0	0.0003
10	560	17	543	11	5	0.0091
11	782	8	775	8	4	0.0051
12	617		617	0	33	0.0521
13	690		690	0	16	0.0207

All area figures are in hectares.
* see text.

The Newly Reworked Data

The data were reworked in the following way, an example being shown in Table 4. Here and in the table, it is assumed for the purposes of exposition that the Faustmann group ratio is five percent.

As stumpage prices have been more or less in constant decline over the study period, it was assumed that no forest in age classes above eleven was in the Faustmann group. This implies that at no time did forest drop into the gentan group, proceed to age class twelve, say, and then, as a result of a price rise or cost fall, revert to the Faustmann group. Thus, the Faustmann group was taken to reside totally in the forests in age classes one to eleven.

As none of the Faustmann group will be felled in age classes one to eight, the Faustmann group was taken as five percent of the total standing area of each of these age classes. Table 3 shows that only 75% of the Faustmann group would enter age class nine, 25% would already have been felled. The standing area of the Faustmann group in age class nine is, therefore, five percent of three quarters of the total area. The areas in age classes ten and eleven were calculated in a similar manner. The standing areas in the gentan group were found by simply subtracting the area of the Faustmann group from the total standing area.

The total area felled was calculated using Equation 1. The area felled in the Faustmann group follows directly from the discussion above. It is zero for all age classes except eight to eleven. For age class eight it is 25% of the standing area of the Faustmann group. For age class nine it is twenty percent of the standing area (0.15/0.75), for age class ten it is two thirds of the standing area in the Faustmann group (0.4/0.6) and all of the remaining Faustmann forest entering age class eleven is felled.

Note that the area felled in the Faustmann group in age class 8 exceeds the total area felled according to Equation 1. The felled area for the gentan group becomes zero. This problem is less acute in earlier data sets where the total areas felled are greater.

The estimated gentan probabilities were found in the same way as illustrated in Table 2 using the standing areas and felled areas in the gentan group. Equation 9 was then used to determine estimates of m and M. This process was repeated with different values for the Faustmann group ratio. For the data in Table 1 the figures associated with the maximum log likelihood were eight percent for the Faustmann group ratio and a mean and variance of 28 and 175 age classes for the gentan probability distribution.

This procedure was repeated with 16 other data sets from the Hokusetsu, Minamimikawa and Shinshiro planning areas in Aichi Prefecture. The data sets dated from 1962 to 1992. A subsequent reorganisation of planning areas means that it is impossible to form a consistent data series beyond that date.

Results

As mentioned above, the high degree of censoring in the data means that the reliability of the results is probably low. It is also clear from the discussion above that other patterns for the distribution of the Faustmann forests are pos-

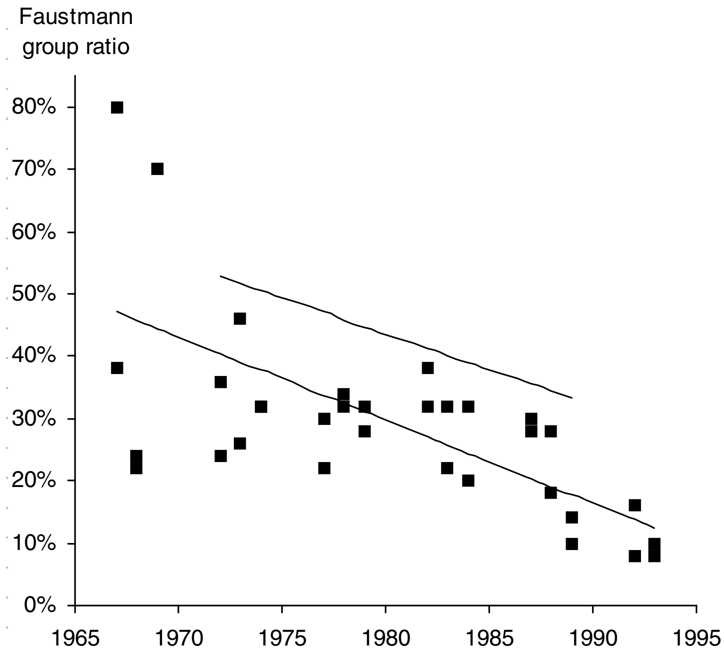


FIGURE 4. THE FAUSTMANN GROUP RATIO FOR SUGI AND HINOKI FORESTS.

sible. Indeed, other patterns were used and, whilst the overall results changed somewhat, the patterns in the results were robust. The results of the analysis can be simply summarised. The Faustmann group ratio has been falling through time and the mean and variance of the gentan probability distribution have both been increasing.

The Faustmann Group

Figure 4 shows the results for the Faustmann group ratio for both sugi and hinoki. The line through the data points is a simple regression against time. No significant difference was found between the time trends for sugi and hinoki. Given the assumptions made and the quality of the data, no great claims are made for the accuracy of the regressions but for completeness the fitted equations are summarised in Table 5.

In Figure 4 the upper line shows the regression of the gentan group ratios from Figure 3 against time. The decline in the proportion of forests under active management found here is consistent with the Japanese models. However, not

TABLE 5. A SUMMARY OF THE REGRESSIONS ILLUSTRATED IN THE DIAGRAMS.

	Dependent Variable	Independent Variable	Intercept Term	Slope	R^2	DF
Fig 4	Faustmann Group Ratio (%)	*Time* (1963 taken as zero)	52.40 (5.19)	−1.33 (5.13)	0.45	32
Fig 5	Mean of the Gentan Probability Distribution	*Time*	5.58 (5.76)	0.841 (5.83)	0.51	32
Fig 6	Variance of the Gentan Probability Distribution	*Time*	−44.71 (2.84)	12.46 (2.85)	0.20	32
Fig 3	Japanese Estimates of the Gentan Group Ratio (%)	*Time*	66.30 (5.28)	−1.13 (5.18)	0.61	17

t-statistics are in parentheses.

only does MAFF appear to assume that more of Japan's forests are under active management than the results here suggest, the implied fall in management is somewhat slower in their model.

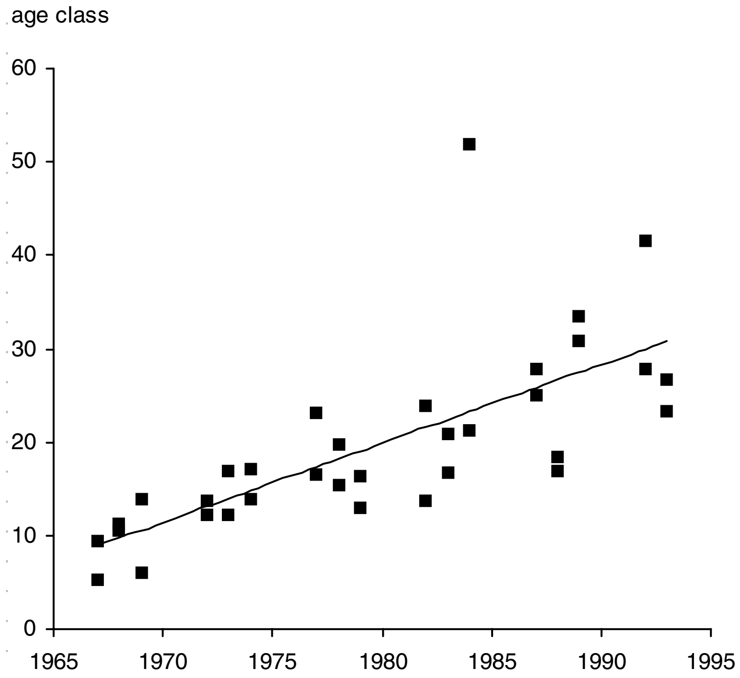


FIGURE 5. THE MEAN OF THE GENTAN PROBABILITY DISTRIBUTION.

Part of the reason for this difference lies in the nature of 'active management'. In the model here active management means that the forest are in the Faustmann group with the rotations shown in Table 3. This band of felling ages is narrower than that resulting from the corresponding Japanese assumption where actively managed forests were modelled by a gentan probability distribution with a mean of ten age classes and a variance of eleven.

Parameters of the Gentan Probability Distribution

A factor not captured in the Japanese models but uncovered here is that the management intensity of unmanaged forests is falling through time. In the Japanese model the output from unmanaged forests was modelled by a constant and low felling probability (Rinyachou, 1984). Here, however, the gentan group has an increasing mean and variance as shown in Figure 5 and Figure 6. Again the straight lines in the diagram are simple regressions against time and no significant difference was found between sugi and hinoki. The implication is that the forests not under active management are falling into ever greater neglect.

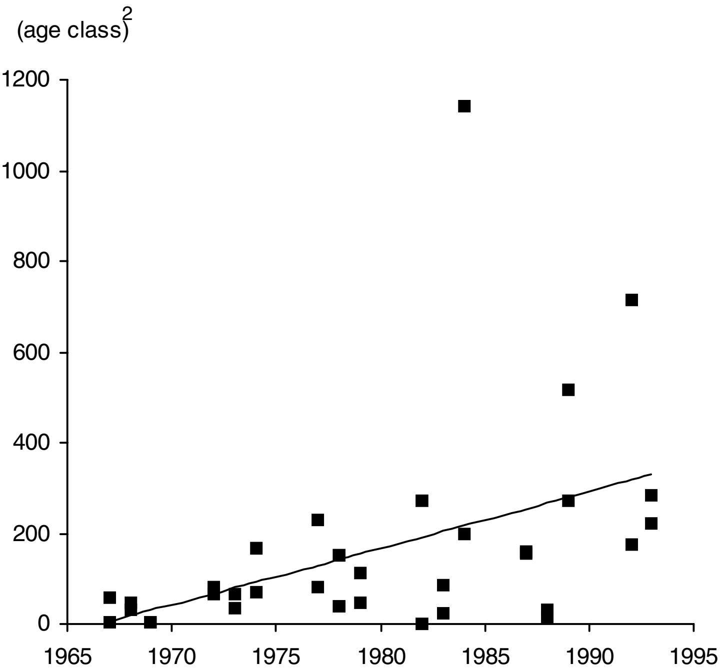


FIGURE 6. THE VARIANCE OF THE GENTAN PROBABILITY DISTRIBUTION.

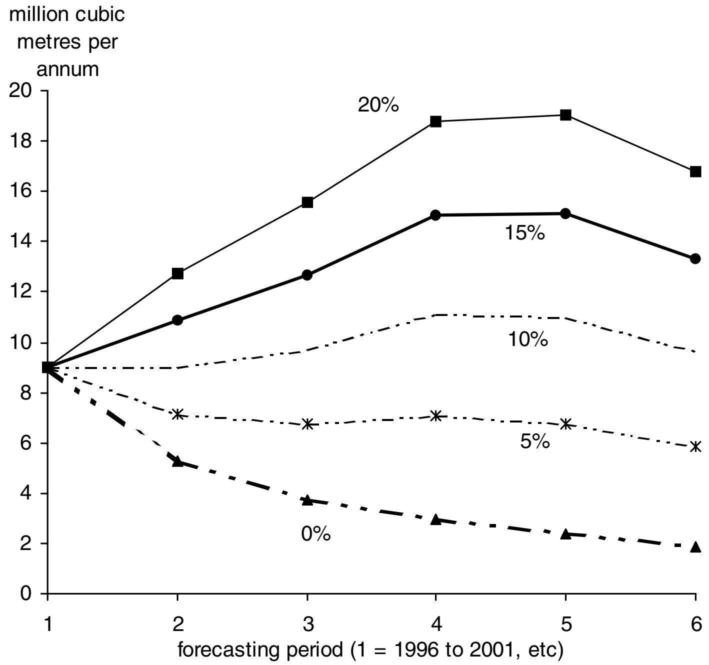


FIGURE 7. FORECASTS OF SUGI LOG OUTPUT.

Forecasts of Output of Sugi

If these results are used for forecasting, the critical nature of the Faustmann group proportion becomes clear. Here simple output simulations for sugi are presented. It can be argued that, as sugi is in competition mainly with North American timber and sells at roughly the same price, any change in the supply of sugi will merely act to increase or decrease imports. It will not greatly influence the price for sugi or American timber. This means that it is possible to produce simple supply forecasts without considering price and demand effects.

This simplifying assumption leads to Figure 7. The forecasts were produced using the age class distribution for sugi man-made forests in all of Japan in 1995. Forests were divided into a Faustmann group and gentan group in the way outlined above. The output from the gentan group was modelled using a gentan probability distribution, the parameters of which were merely extrapolated from the equations shown in Figures 5 and 6. The total log output was calculated for various Faustmann group ratios from zero to 20% with this ratio held constant over the forecasting periods.

For Faustmann group ratios below 5% to 6% the output of sugi declines into the future. For higher levels, the output increases, reaches a peak and then declines as the bulge in the age class structure moves past the assumed felling ages for the actively managed forests. With relatively small changes in the Faustmann group ratio it is possible to simulate falling, stable or increasing outputs and, therefore, different import patterns. Furthermore, Figure 4 shows that the Faustmann group ratio is near this critical value of 5% to 6%.

With hinoki, such a simulation is impossible. Hinoki's price is about twice that of sugi and perfect substitutability may not be assumed. Recent models suggest that the demand for hinoki was relatively inelastic so increases in output rapidly depress price. Hence, the demand side of the market would have to be taken into account in simulating changes in output (Blandon, 1999).

Conclusions

The implication of the research here is that the decline in domestic log production in Japan is attributable to two factors, only one of which is captured in the Japanese models. The first is the reduction in the proportion of forest owners who are actively managing their forests and the second is the reduction in management intensity of those forests not under active management.

These two factors probably derive from the same basic cause: the declining profitability of forestry in Japan. Over the period covered by the data, 1965 to 1995, the average nominal industrial wage rate rose over 11 times while the nominal stumpage price for sugi rose by 25% and that for hinoki by 2.6 times. Furthermore, these figures underestimate the true decline in forestry's profitability. Over the same period, the availability of part-time work in rural areas has increased, raising the opportunity cost of labour in the agricultural off-season. The topography of Japan's forests is such that the mechanisation of operations has not been able compensate for this increase in costs.

Certainly, this is the explanation that the Japanese would favour. Their Forestry White Papers are fond of publishing the ratio of the wage rate in felling to the stumpage price of sugi. In 1965 one cubic metre of sugi stumpage was equivalent to 7.7 man-days. In 1995 the figure had fallen to around one. These figures are used by the Japanese in defence of their gentan group. The fall in timber prices has led to a move in the extensive margin of forest cultivation and, therefore, a reduction in forest management. Here, however, the argument applies to the Faustmann group.

At the same time, this fall in profitability of forestry would probably lead to a decrease in management intensity of those not actively managing their forests. The growth of the urban economy has meant that the rural areas of Japan are in decline. The population is ageing as the young find better-paid jobs in urban centres. This means that many of those responsible for managing the forests are now in their seventies and eighties. This might be responsible for their reduced felling probabilities in group of unmanaged forests. This could be the result of some form of bequest motive or as a result of the increased disutility of the labour involved in forest management.

This casual empiricism is supported by data from the Forestry Censuses. Between 1960 and 1990 the proportion of private forest owners selling timber fell from 26.9% to 5.2%. This would be picked up in this model as a fall in the size of the Faustmann group. However, the drop in the number tending their forests in a way other than thinning or felling fell from 56.6% to 27.3%: a smaller drop (Akaha, 1992). The bi-modal price-size curve could here be reinforcing a bequest motive with forest owners leaving their forests until the actual income from felling (rather than the net present value) is larger than it would be at Faustmann-based rotations. It is possible to speculate that the absence of a developed market for land and growing incomes from other sources reduce the incentives to manage according to Faustmann-style principles. With felling for many owners a 'once-in-a-lifetime' operation it is possible that owners maximise the income from felling rather than NPV.

The price differential between hinoki and sugi suggests that the Faustmann group for hinoki ought to be larger than that for sugi and, that hinoki forests in the gentan group should exhibit different gentan probability distributions from those of sugi. However, the results presented here suggest not. Part of the reason for this might be the fact that hinoki is often planted 'further up the hill' than sugi and so has somewhat higher extraction costs. In part this would reduce the profitability of hinoki, although the figures suggest that this is not the whole story.

Given the declining real timber prices in Japan over the study period, it would be easy to correlate the Faustmann group ratio and the mean of the gentan group with stumpage price and the brief discussion above could act as an economic justification for doing so.

If the brief discussion above is correct, such a model would allow the simulation of the effects of government policy by allowing the Faustmann group ratio to alter as a result of changes in, say, roading or thinning subsidies. Also, changes in the demographics of rural Japan which have led to falls in the management intensity could be related to the parameters of the gentan probability distribution. With better data, the approach here offers an interesting approach to forecasting domestic production, and therefore import levels.

Quite clearly, more research is needed in this area. The fact that the Faustmann group appears to be hovering around the level which divides increasing output from decreasing domestic log production shows the knife edge that domestic forestry in Japan is on. Figure 7 shows that, even a relatively small success in policy would lead to an increase in output larger than the processing capacity of Japan could absorb. Increases in the domestic price of timber in Japan can be caused by policies in the USA and Canada. If further work was to show, as might be expected, that the Faustmann group ratio is related to the timber price, a withdrawal of stands from production on, say, the West Coast of North America could easily lead to increases in output in Japan and reductions in imports.

With the current age class structure of Japan's man-made forest small changes in the parameters of the models lead to large changes in the forecasts, suggesting that simple extrapolations of output are not a luxury available to forecasters in this field.

REFERENCES

Akaha, T., 1992. *Nihon Ringyou no Seisan Kouzou*. Nourin Toukei Kyoukai, Tokyo, 307p. (J)

Blandon, P. R., 1991a. *Studies on Gentan Probability Theory and the Felling Behaviour of Japanese Private Forest Owners*. The University of Tsukuba, Tsukuba, Japan, 389p.

Blandon, P. R., 1991b. Censored Sample Theory and the Forecasting of Output from Japanese Private Forests (I). *Journal of the Japanese Forestry Society*, 73(5), 187–196.

Blandon, P. R., 1993. Unmanaged Forests and Forecasting Using the Gentan Probability Distribution. *Journal of the Japanese Forestry Society*, 75(6), 484–492.

Blandon, P. R., 1994. Movements in the Parameters of the Gentan Probability Distribution. *Journal of the Japanese Forestry Society*, 76(1), 1–9.

Blandon, P. R., 1999. *Japan and World Timber Markets*. CAB International, Wallingford, UK, 242p.

Fujimori, T., 1985. Edauchi to Ikurin Gijutsu. Nihon Ringyou Chousakai, Tokyo, 224p. (J)

Iehara, T., 1989. Hinoki no Riyuu to Souzaikakaku no Suitei ni kan suru Tenbou. In, *Proceedings of the 100th Conference of the Japanese Forestry Society*, Japanese Forestry Society, Tokyo, pp. 157–158. (J)

Iehara, T. & Kurokawa, Y., 1990. An Economic Evaluation for Reforestation with Hinoki on Low-productivity Forest Sites. *Journal of the Japanese Forestry Society*, 72(1), 34-45. (JA)

Ishihara, T., 1980. *Shinrinkoujou e no Michi*. Seibunsha, Tokyo, 198p. (J)

Kurimura, T., 1980. *Sanrin no Houka*. Nihon Ringyou Gijutuskyoukai, Tokyo, 644p. (J)

Rinyachou, 1984. *Kokusan Seizaikyoukyu Sisutemu Keisan Moderu Kaihatsu Chousahoukokushou*. Rinyachou Kikakuka, Tokyo, 122p. (J)

Sakaguchi, K., 1983. *Sugi no Subete*. Zenkoku Ringyou Kairyou Fukyoukai, Tokyo, 629p. (J)

Shinrin Keikaku Kenkyuukai, 1987. *Aratana Shinrin Ringyou no Chouki Bijyon*. Shinrin Keikaku Kenkyuukai, Tokyo, 415p. (J)

Shinrin Keikaku Seido Kenkyuukai, 1992: *Shinrin Keikaku no Jitsumu*. Shinrin Keikaku Seido Kenyuukai, Tokyo, 574p. (J)

Shinrin Kihon Keikaku Kenkyuukai, 1997. *21 Seiki wo Tenbou Shita*

Shinrin Ringyou no Chouki Bijyon. Shinrin Kihon Keikaku Kenkyuukai, Tokyo, 416p. (J)

Suzuki, T., 1965. Mokuzai no Seisan Yosoku ni tsuite II. In, *Proceedings of the 76th Conference of the Japanese Forestry Society*, Japanese Forestry Society, Tokyo, pp. 9–12. (J)

Suzuki, T., 1972. Ringyou ni okeru Kakuritsukateiron no Ouyou I. *Journal of the Japanese Forestry Society*, 54(7), 234–237. (J)

Suzuki, T., 1973. Ringyou ni okeru Kakuritsukateiron no Ouyou II. *Journal of the Japanese Forestry Society*, 55(7), 234–237. (J)

(J) In Japanese
(JA) In Japanese with English abstract