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The Competitiveness and Return Components of NIPF Ownership in Finland

ABSTRACT

A method for estimating return on and risk of non-industrial private forest (NIPF) ownership involving the innovation of dividing the return into (i) felling, (ii) price change, (iii) change in the growing stock and (iv) silvicultural cost components has been developed. Comparison is made between stumpage price change and inflation as well as between forests and other assets, which are housing, offices, stocks and their subclass forest industry stocks as well as bonds and debentures. These results are based on a complete count of the stumpage prices, silvicultural costs, felling volumes and national forest inventory (NFI) data.

Forest ownership produced a real return of only 2.6% in the 1972–2003 period, housing 4.6% and forest industry stocks as much as 7.6%. The nominal return on forest ownership of 8.4% consisted of stumpage price change rate 4.6%, commercial fellings 3.1%, costs –0.35%, and volume change component 1.0%. Surprisingly, stumpage price change did not exceed the inflation level of 5.8%. The correlation with forest ownership was statistically significant only with private housing. Competitiveness benchmarking places forests slightly behind housing. However, optimal portfolios, which also recognise correlations, place housing behind forests. In all, financial investments clearly outperformed real investments in the low inflation 1987–2003 period.

Key words*: asset class, forest industry, forest land evaluation, NIPF ownership, portfolio management, return, risk*

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1. INTRODUCTION

1.1. Non-industrial private forests (NIPFs) in portfolio management

There is no statistically representative sample of the bookkeeping network of forest holdings for profitability studies in Finland, although some results have been published (see e.g. Peltola 2003). The lack of comprehensive research has inspired this *portfolio management* analysis, focusing on the *development of return estimation* and the development of the *return decomposition* methodology. The refinement of relevant empirical data was the objective of the study, which is intended to cover (i) all asset classes, (ii) NIPF ownership, and (iii) the components of the return on NIPF ownership such as stumpage price, fellings, costs, and change in forest value. In all, the present study is the first to provide a comprehensive national-level risk and return coverage, which complements previous results such as Heikkinen (2002) by estimating the return on forest ownership series instead of using stumpage price series only.

1.2. The purpose of the study

The purpose of this study is to compare the return on forest-owning with other asset classes. First, the development of the *return and risk estimation method* of NIPF ownership is a contribution. Second, the *solution of the national-level return* by splitting it into (i) stumpage price change, (ii) silvicultural costs and (ii) the growing stock net increment components, the last of which are also divided into (iv) fellings and (v) growing stock value change components has been introduced here. Third, the *various asset class returns of the whole market portfolio* were estimated. Fourth, the *NIPFs* were compared with *other asset classes,* applying risk-adjusted ratios of risky asset classes. Finally, the *return and split methodologies* developed here were applied to local empirical evidence for 1972–2003.

1.3. Previous studies

Risk inclusion originated from the pioneering work on portfolio theory of Markowitz (1952). Since then portfolio management and its developments have been extensively researched, and their application to forestry has been discussed in Zinkhan et al. (1992). All portfolio theory (PT) and capital asset pricing model (CAPM) studies applied to forestry have been used in this study. Cubbage et al. (1989) evaluated timber risk and return during 1952–1986 by using the CAPM analysing the performance of individual tree species. Binkley & Washburn (1990) also evaluated timber and land risk 1956–1986 by using CAPM, finding that the financial risk on forestry investments was larger than that of government bonds but smaller than corporate bonds. Washburn & Binkley (1990a) estimated CAPM from period-average asset values applying both a geometric and an arithmetic mean. Washburn & Binkley (1990b) tested the informational efficiency of stumpage markets for pine sawlogs.

Thomson (1991a) examined risk and return on timber assets along with the financial assets of common stocks, corporate bonds, US Government bonds and treasury bills over a 50-year period. Thomson (1991b) estimated the return on forestry by tree species and financial market investment. Wagner & Ridout (1991) compared CAPM and the income growth model, and found that adding forest assets to a well-diversified portfolio would increase the expected return while not substantially contributing to the variance. Wagner & Rideout (1992) analysed the stability of CAPM parameters using the cusum signal test and the log-likelihood test, which showed that the parameters are unstable. Blumenstock (1993) estimated return levels by using a real-estate index constructed by banks and insurance companies with considerable investments in timberland. Wagner et al. (1995) compared CAPM and traditional investment analysis methods even with very low explanation percentages of 0.09%–27%. Thomson (1997) compared returns from fir and pine stands with financial assets in 1927–1994.

Caulfield (1998) compared timberland and other asset classes, the last of which included large capitalisation and small capitalisation US stocks, commercial real estate, foreign stocks, long bonds and treasury bills. Heikkinen (1999) constructed cutting rules for the timber harvesting planning of a forest holding with four merchantable stands together with stocks, using the portfolio optimisation with the estimated returns on both stands and stocks. Lönnstedt & Svensson (2000) compared NIPF ownership with grain and milk production as well as with shares and bank deposits, while Sun & Zhang (2001) examined CAPM and arbitrage pricing theory using data consisting of forestry-related assets, a farmland index and other assets, including government bonds. Heikkinen (2002) tested the co-integration of logarithmic monthly stumpage prices with stocks, government bonds and deposits, using the first differences of the logarithmic prices and applying vector autoregressive (VAR) models and a vector error correction (VECM) model. In the case of VAR models with one lag, the expected mean return on spruce sawlogs was roughly 6%, and stocks and forest were preferred. Adding a one lag co-integration part to this VAR model produced a VECM model. However, this addition dropped the expected mean return to –2% and, by contrast, preferred government bonds and bank deposits.

2. MATERIALS AND METHODS

2.1. The National Forest Inventory (NFI) and Forest Statistics Information Service (FSIS)

The results are based on the national forest inventory (NFI) and forest statistics information service (FSIS), which are not merely a sample of forest holdings and areas, but systematic databases. The National Forest Inventory (NFI) has a long tradition in Finland. The sixth NFI was carried out in 1971–1976, the seventh in 1977–1984, and the eighth in 1986–1994. Since the NFI9 results from 1996–2003 are available from twelve forest centre areas (Peltola 2003), NFI 8 is also used to cover the years after 1994 by extrapolation for Lapland.

There are two points of focus: (i) *roundwood assortment volume* and (ii) *net roundwood assortment increment.* In the three inventories there are thus three measured *growing stocks* of all six (6) roundwood types and *net increment* point estimates of three (3) tree species, pine, spruce, and broadleaves. These estimates are for all nineteen (19) Forestry Board Districts (FBDs). The forest statistics information service (FSIS) provides stumpage prices, silvicultural costs and commercial felling. The detailed measurement methodology developed to tackle the separate estimation problems of growing stock, net increment, roundwood assortment and commercial roundwood fellings has been described in Lausti & Penttinen (1998a).

2.2. The Definition of the return on non-industrial private forest (NIPF) ownership

First, the value of a roundwood type in all NIPFs is considered. Note that the return on roundwood assortment has been estimated separately for each type a, a = 1,2,...,6, and each year y, y = 1972...1998 by Lausti & Penttinen (1998a). The estimation technique by each roundwood type a was based on the US research tradition (see Binkley & Washburn 1990).

Second, the return on NIPF ownership $r_{y,NIPF}$ during year y at the national level is produced here by estimating the sum of the growing stock, the change in the growing stock and felling values across the roundwood assortment according to approach (1):

$$(1) \qquad r_{y,NIPF} = LN\left(\frac{\sum_{a=1}^{6} P_{ya}(V_{y-1,a} + I_{ya} - F_{ya}) + \sum_{a=1}^{6} P_{ya}F_{ya} - C_y}{\sum_{a=1}^{6} P_{y-1,a}V_{y-1,a}}\right),$$

where the sigma Σ stands for a sum and *a* is roundwood type, *y* the year considered, $P_{ya}(P_{y-1,a})$ roundwood type *a* stumpage price at the end of year *y* (at the end of year $y-1$) , $V_{y-1,a}$ roundwood type *a* volume at the end of year $y-1$, I_{ya} roundwood type *a* net increment stock during year *y* , F_{ya} commercial fellings of roundwood type *a* during year *y* , C_y silvicultural and forest improvement costs reduced by state subsidies during year *y*. *LN* stands for natural logarithm. The commercial fellings are needed, however, only for the return component split. Recall that Washburn & Binkley (1990b, p. 398) first used differences in the natural logarithm in calculating rates of change in stumpage price, stock market value and inflation.

Third, the bare land value is considered. Some studies include this value (LV_y) in the return formula (1) above, both LV_y in the numerator and LV_{y-1} in the denominator (Thomson, 1991a, 1991b, 1997). This inclusion is not actually corroborated by the empirical findings noted in Klemperer (1996), who demonstrated that, at least in the case of large tracts with mature timber, the price of forest land may well be lower than the felling value, which is also the case in the Finnish forestry (Hannelius 2000).

2.3. The Competitiveness of NIP forests as investments

The return and risk of all asset classes have been assessed, and compared with NIPF ownership. In order to benchmark the competitiveness of various assets for investors we relate risk and return across asset classes using the ex post Sharpe ratio S_{AC}, which compares the return of each asset class AC against the benchmark asset class BM (Sharpe 1994):

(2) $$S_{AC} = \frac{r_{AC} - r_{BM}}{\sigma_{AC}}$$

where r_{AC} is the average of annual historic returns $r_{y,AC}$ on asset class AC, y = 1972–2003, r_{BM} the average of annual returns and $r_{y,BM}$ on the benchmark asset class BM. The government bonds were chosen to proxy the ″riskfree″ benchmark asset class BM. Moreover, σ_{AC} is the standard deviation of annual historic excess returns $r_{y,AC}$-$r_{y,BM}$.

2.4. The Decomposition of the return on NIPF ownership

The decomposition methodology has been developed for each roundwood type by Lausti & Penttinen (1998a). The return on NIPF ownership $r_{y,NIPF}$ at the *national level* (1) is considered next. The first phase concerns the cost component. One obtains the cost component and the price change and net value increment component ignoring fellings for the present. The expression inside the logarithm (of equation 1) can be represented as the product of two parts, the last of which gives the cost component $r_{y(c)}$ of the return (for the derivation, see Appendix)

(3) $$r_{y(c)} = LN\left(1 - \frac{C_y}{\sum_{a=1}^{6} P_{ya}(V_{y-1,a} + I_{ya})}\right).$$

In the second phase, the net value increment component splits into the price change component $r_{y(p)}$

(4) $$r_{y(p)} = LN\left(\frac{\sum_{a=1}^{6} P_{ya} V_{y-1,a}}{\sum_{a=1}^{6} P_{y-1,a} V_{y-1,a}}\right),$$

and the net increment (volume change) component $r_{y(i)}$, which is similarly

$$(5)\qquad r_{y(i)} = LN\left(1+\frac{\sum_{a=1}^{6} P_{ya} I_{ya}}{\sum_{a=1}^{6} P_{ya} V_{y-1,a}}\right)$$

based on the properties of the logarithm (see Appendix). Note that the first and second phase partitions (3), (4), (5) of the national level return $r_{y,\,NIPF}$ (1) are precisely additive, i.e. $r_{y,\,NIPF} = r_{y(p)} + r_{y(i)} + r_{y(c)}$.

In the third phase of the break-up, the net increment (volume change) component $r_{y(i)}$ (5) will be divided further into fellings $r_{y(f)}$ and the volume change in the growing stock $r_{y(v)}$ components, which are (see Appendix)

$$(6)\qquad r_{y(f)} = LN\left(1+\frac{\sum_{a=1}^{6} P_{ya} F_{ya}}{\sum_{a=1}^{6} P_{ya} V_{y-1,a}}\right),$$

and the volume change in the growing stock component $r_{y(v)}$; similarly

$$(7)\qquad r_{y(v)} = LN\left(1+\frac{\sum_{a=1}^{6} P_{ya}(I_{ya} - F_{ya})}{\sum_{a=1}^{6} P_{ya} V_{y-1,a}}\right).$$

Note that the last decomposition of the net increment component $r_{y(i)}$ (5) into fellings $r_{y(f)}$ and volume change $r_{y(v)}$ is additive but not exact, i.e. $r_{y(i)} \cong r_{y(f)} + r_{y(v)}$. However, the error term is negligible, and because the relative volume change caused by the net increment I_y is small, the relative change caused by fellings F_y is typically even smaller (see Appendix). In all, the national-level NIPF return in (1) has yielded an additive decomposition $r_{y,\,NIPF} \cong r_{y(p)} + r_{y(f)} + r_{y(v)} + r_{y(c)}$.

2.5. Sensitivity analysis of the return on NIPF ownership

The sensitivity of the return on forest ownership can be analysed as decreasing or increasing the non-monetary items in the felling value using the sensitivity parameter s , but leaving monetary transactions values such as sales revenues from commercial fellings and silvicultural costs untouched. It relates the felling values of forests to their market values. The return on forest ownership (1) is defined whenever s is included:

$$(8)\qquad r_{y,NIPF} = LN\left(\frac{s\left\{\sum_{a=1}^{6} P_{ya}(V_{y-1,a} + I_{ya} - F_{ya})\right\} + \sum_{a=1}^{6} P_{ya} F_{ya} - C_y}{s\left\{\sum_{a=1}^{6} P_{y-1,a} V_{y-1,a}\right\}}\right)$$

The felling values of forest holdings have in most cases been higher locally than their actual market prices, $0 < s < 1$. For example, Hannelius (1988, 2000) has shown that the actual market values were lower by 10–20% on average than the felling values.

2.6. Private housing and offices

Private housing data includes a large sample, covering the 20 largest cities in Finland. It also includes smaller cities that have been combined into larger regions. The return on housing and office investment consists of capital appreciation and the rent component minus the cost component. Trade, rent and cost statistics for private housing have been constructed by Statistics Finland. Returns on offices, which are based on price changes, rents and costs, were calculated in a similar way.

The returns on offices are only available for Central Helsinki in 1972–1997. However, a comprehensive index that includes all the major cities in Finland has been used in 1998–2003. This index includes offices and other commercial real estate as well. The returns have been constructed by the KTI Institute for Real Estate Economics.

2.7. Bonds and debentures

Since there is no comprehensive bond or debenture index available in Finland for the period before 1992, the returns on public bonds were derived from data on government tax-free and non-indexed bonds. The bond sample has fluctuated from only one to three bonds before 1992. The return on taxable corporate debentures has been calculated as the arithmetical mean of the effective yields on fixed-rate ordinary bonds, debentures and other bonds from all issuers except the central government. The remaining maturity of the debentures is generally 3–6 years. The corporate debenture sample has fluctuated from one to three bonds at various times. The Sampo bond index has been used for period 1992–2003.

2.8. Stocks

The WI index returns were used for the period 1972–1989. This index is the value-weighted sum of individual stock return indices based on the average trading price for the day or, in its absence, the bid price corrected for dividends, splits, stock dividends and new issues.[1] From 1990 to 2003 the Helsinki Stock exchange Hex return index has been used. This is also a market value-weighted index. All the stock returns include the dividend payments and share issues of the companies. All returns and indices are logarithmic.

1 The WI index, described in greater detail in Berglund et al. (1983), has been calculated by the Swedish School of Economics.

3. RESULTS

3.1. The competitiveness of NIPF ownership

The felling value of NIP forests in 2003 currency has slightly decreased from €44 billion in 1972 to €36 billion in 2003, but its proportion of the total market portfolio has dropped from 29% (1972) to 6.8% (2003). Moreover, the risk-adjusted Sharpe ratio of NIPF ownership (0.01) exhibited a lower level than that of housing (0.18), and was well below that of stocks (0.20).

TABLE 1. Average annual returns, standard deviations and Sharpe ratios (according to formula (2)) and the average market value shares of various asset classes in Finland 1972–2003 (statistical analyses in Appendix).

TOTAL PERIOD: 1972–2003 (* means the 1972–1994 period)	Return Return %	Risk Standard Deviation %	Risk-adjusted Ratio Sharpe ratio	Market Share Percentage %
Offices	15.5	15.6	0.46	28.4
Stocks	14.8	32.5	0.20	11.8
– Forest industry stocks	13.4	27.7	0.18	2.8
Corporate Debentures	10.9*	3.3*	0.58*	2.1
Housing	10.4	11.4	0.18	37.3
Forest Ownership	8.4	13.4	0.01	15.7
Government Bonds	8.3	5.5	0.00	4.7
Inflation rate	5.8	4.7		
Market Portfolio	12.9	14.2	0.32	100

The government bond is considered ”riskfree”. Offices and stocks form the high return, high-risk classes, while housing and NIPF ownership represent medium return and medium risk (cf. Penttinen et al. 1996).

There are significant positive correlations between forest ownership and private housing returns, 0.55, and between forest ownership returns and offices, 0.37. The correlation between forest ownership returns and stocks returns is very low, only 0.15, and that between forest ownership and corporate debentures even negative at –0.46.

Finally, all optimal asset allocation portfolios were considered. For a given riskfree asset r_f, there is a portfolio called the tangency portfolio such that this optimal portfolio yields the maximum Sharpe ratio of all portfolios of risky assets (Campbell et al. 1997, p. 188). Modifying r_f gives the efficient frontier. NIPFs were accepted in the portfolio only for values $r_f < 2.9\%$.

TABLE 2. Correlation matrix of different asset classes (Annual data 1972-2003, except for corporate debentures 1972–1994).

	Private Housing	Corporate Debentures	Offices	Forest Ownership	Government Bonds	Stocks	Inflatio Rate
Private Housing	1	–0.42 *	0.56 ***	0.55 ***	–0.25	0.45 **	0.27
Corporate Debentures	–0.42 *	1	–0.23	–0.46 *	0.64 ***	–0.21	–0.09
Offices	0.56 ***	–0.23	1	0.37 *	–0.30 +	0.01	0.5 **
Forest Ownership	0.55 ***	–0.46 *	0.37 *	1	–0.28	0.15	0.28
Government Bonds	–0.25	0.64 ***	–0.3 +	–0.28	1	0.08	–0.25
Stocks	0.45 **	–0.21	0.01	0.15	0.08	1	–0.15

***** Statistically significantly different from zero at 0.1% level**
**** Statistically significantly different from zero at 1% level**
*** Statistically significantly different from zero at 5% level**
+ Statistically significantly different from zero at 10% level

Surprisingly, apartments were not accepted in the portfolio yet for interest rates 1–3%. Unlike Sharpe ratios, the covariances dropped housing behind NIP forest.

3.2. Components of Return on Forest Ownership

The average annual real return on forest ownership was 2.6%, and the nominal return 8.4% in 1972–2003. This return will now be divided into various components. Surprisingly, the price change component has been 1.2% less than the inflation rate.[2] The commercial fellings component has been on average 3.1% and the volume change component 1.0%.

Annual returns and their components reveal considerable volatility in price changes, cuttings and in changes in the value of the growing stock. Not only price change but the total return may also be negative, which actually happened during the recession in 1992.

3.3. Sensitivity considerations

The sensitivity parameter level $s = 0.8$ has been suggested by Hannelius (1988, 2000). Then the average nominal return on forest ownership has increased from 8.39% to 9.07%, but the

2 Finnish Forestry Statistical Yearbook 2003 reports a clearly positive stumpage price index trend both for 1950–2003 and 1987–2003 (Peltola 2003, p. 147).

TABLE 3. Average annual returns (Logarithmic Returns) and standard deviations of NIPF ownership components (the equation number refers to the definition of the component concerned) in 1972–2003.

	Return	Standard Deviation	Equation number
Price Change Component	4.6%	13.4%	(4)
Commercial Fellings	3.1%	0.68%	(6)
Volume Change Component	1.0%	0.70%	(7)
– Costs	0.35%	0.06%	(3)
= NIPF ownership, nominal	8.4%	13.4%	(1)
Inflation Rate	5.8%	4.7%	
= NIPF ownership, real	2.6%	12.9%	

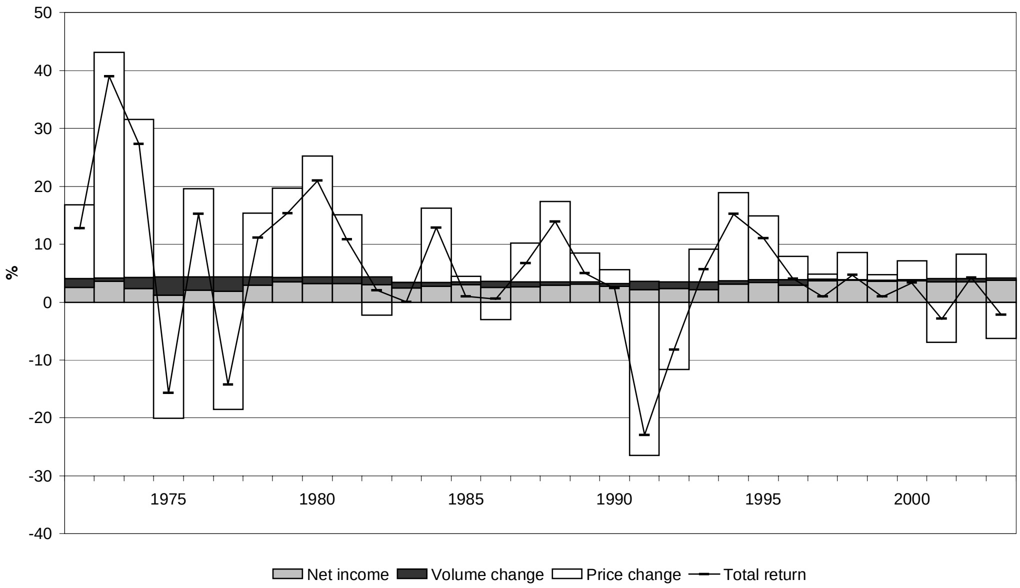

FIGURE 1. Return components of NIPF Ownership in 1972–2003

standard deviation only from 13.42% to 13.47% in 1972–2003. Thus the annual nominal return on forest ownership improved by an average of 0.68%, which means that the sensitivity parameter of the felling values is very significant for the level of the estimated rates of return.

Even with a relatively high reduction in fellings values, say 25%, the return on forest ownership of 9.29% would not achieve that of private housing at 10.4%.

TABLE 4. The effect of the sensitivity parameter s on annual average forest ownership return

Parameter *s*	Return	Standard Deviation	Average Return
1.00	8.39%	13.42%	+ 0.00%
0.95	8.53%	13.43%	+ 0.14%
0.90	8.69%	13.44%	+ 0.30%
0.85	8.87%	13.46%	+ 0.48%
0.80	9.07%	13.47%	+ 0.68%
0.75	9.29%	13.49%	+ 0.90%

4. SUMMARY

Profitability comparison between NIPF ownership and other investment classes originates in the US accounting approach, which utilizes property values, and portfolio theory (Markowitz 1959). Asset classes demonstrate considerable differences in returns and risks, and especially in risk-adjusted competitiveness. Unlike most US studies, forests do not reduce portfolio risk, but demonstrate a relatively high risk, which fluctuates with the market. Even their so-called systematic risk is high 0.91 (Lausti & Penttinen 1998b). Moreover, the real return of 2.6% was clearly less than in many US studies (such as Binkley et al. 1996). Competitiveness benchmarking between asset classes placed forests behind housing, but efficient portfolios placed housing well behind forests, the distinction being caused by the correlation structure.

The relative market value of NIP forests has declined dramatically in the total market portfolio from 29% in 1972 to 6.8% in 2003. The market portfolio could be grouped into (i) high risk and high return asset classes such as stocks and offices, (ii) medium risk, medium return assets such as housing and forests, and (iii) low risk, low return classes such as government bonds. The component split of the NIPF ownership return showed that, against expectations, the price change component of NIPF ownership was as much as 1.2% less than the inflation level in 1972–2003, which makes the stumpage price trend critical. However, fellings have approached net increment, especially in recent years. The results have been made available by the Forest Statistics Information Service (FSIS) for day-to-day use (Penttinen & Lausti 2002) and are accessible on the METINFO (2004) Internet service.

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APPENDIX

The cost decomposition

Consider the NIPF return $r_{y,NIPF}$ in (1). Separating the ratio $[\Sigma P_{ya}\ (V_{y-1,a} + I_{ya})]/[\Sigma P_{y1,a}\ V_{y-1,a}]$, which will be denoted by $[P_y *(V_{y-1} + I_y)]/[P_{y-1} * V_{y-1}]$ from $1 - C_y/[\Sigma P_{ya}\ (V_{y-1,a} + I_{ya})]$ inside the logarithm shows that the first term is the logarithmic expression $LN\{[P_y *(V_{y-1} + I_y)]/[P_{y-1} * V_{y-1}]\}$ and the second the logarithm expression in (3). Note that here the asterisk * stands for the total roundwood assortment *a, a* = 1, 2, ..., 6.

The price change and volume increment decomposition

Furthermore, consider the first term $LN\{[P_y * (V_{y-1} + I_y)]/[P_{y-1} * V_{y-1}]\}$ of the above decomposition of $r_{y,NIPF}$. One can write the expression inside the logarithm above as a product of two expressions, [Py *Vy−1]/[Py−1 * Vy−1] and $\{1 + [P_y * I_y]/[P_y * V_{y-1}]$. When the logarithm is taken, it forms an addition to the logarithms LN {[Py * Vy−1]/[Py−1 * Vy−1]} (4) and $LN\ \{[1 + [P_y * I_y]/[P_y * V_{y-1}]\}$, (5) appear.

The fellings and change in growing stock decomposition

Consider the second term LN $\{1 + [P_y * I_y]/[P_y * V_{y-1}]\}$ (5) above of the previous decomposition. Recall that $I_y = (I_y - F_y) + F_y$. Using the sum expansion for I_y above in the logarithm expression (5) above, one obtains a product $\{1 + [P_y * F_y]/[P_y * V_{y-1}]\}$ and $\{1 + [P_y * (I_y - F_y)]/[P_y * V_{y-1}]\}$, and an additive error term $-\{[P_y * (I_y - F_y)]\ [P_y * F_y]\}/\{[P_y * V_{y-1}]^2\}$ inside the logarithms. The logarithms of the first two terms yield (6) and (7).

This error term has been analysed in detail in the case of a single roundwood type by Lausti and Penttinen (1998a). Here only a scalar upper limit can be demonstrated. Note that where (a) no fellings and (b) fellings achieve a net increase, the error term equals zero. If (6) and (7) were positive, they would decrease the logarithm of the error term above. Where both fellings and growing stock volume increase are equal, $I_y - F_y = F_y$, the error attains its maximum. In this case the error term is LN $\{1 - [P_y * (I_y - F_y)]\ [P_y * F_y]\}/[P_y * V_{y-1}]^2\}$

Suppose that the net increase I_y is of size 4% of the original volume V_{y-1} as suggested by the National Forest Inventory and that the fellings are half the volume increment $F_y = 0.5\ I_y$, which tends to maximize the error term. The scale of the error term inside the logarithm is then 0.0008 or 0.08%, and the scale of the logarithm above is $-0.0008 - 0.0008^2/2 - 0.0008^3/3 - \ldots > -0.001$, according to its series expansion. This magnitude is not relevant in the empirical results.

The statistical analysis of the excess return series

Some skewness and kurtosis was present in each series but, according to the *Jarque-Bera* normality test, none of the series was non-normal at a significance level of 5% (p = 5% in the sequel as well). The stationarity was tested with the modified *Phillip-Perron* unit root test, but the hypothesis of difference stationarity was rejected for each of the series. Residual autocorrelation with *Godfrey*'s general autocorrelation tests for ARMA errors produced a significant result for apartments and offices because of a small autocorrelation of these series at lag one. *Engle*'s LM test statistic for *autoregressive conditional heteroskedasticity* (ARCH) also yielded a significant value for bonds and offices, but the ARCH property of these two series could not be convincingly estimated. Moreover, the best *vector autoregressive* (VAR) model proved to be a VARX(1) model with two endogenous variables, forest and apartments, and two exogenous regressors, stocks and offices. The forest returns could be explained by simultaneous office returns and by lagged stock returns. On the other hand, apartments could similarly be explained by simultaneous stocks and offices returns and by the lagged forest returns.