The informational efficiency of the Vancouver Log Market and the financial risk of holding logs in storage

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Viewed on an annual or quarterly basis, the Vancouver Log Market appears to process price information efficiently, but apparently does not do so for monthly trading intervals. For the longer holding periods the Vancouver Log Market passes one of the fundamental tests for an efficient market, and as a consequence there are few gains to make by speculating in this market on the basis of technical analysis of past price movements. Explanations for lack of information efficiency in the monthly returns requires further study. Holding logs does not appear to entail a significant amount of systematic or market risk if the holding periods are one quarter or less. Producers can hold log inventories in the Vancouver Log Market without increasing the financial risk of their enterprises.

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Considéré sur une période annuelle ou trimestrielle, le Marché des Grumes de Vancouver semble véhiculer efficacement l'information sur le prix, mais apparemment il n'en est pas ainsi pour les intervalles mensuels. Relativement au maintien d'inventaires sur de plus longues périodes, le Marché des Grumes de Vancouver se conforme à un des tests fondamentaux d'un marché efficace et conséquemment, peu d'avantages peuvent être obtenus sur ce marché en spéculant suite à une analyse technique des mouvements de prix antérieurs. D'autres études sont nécessaires pour expliquer le manque d'efficacité de l'information provenant des ventes mensuelles. Si le maintien de grumes se poursuit durant des périodes d'un trimestre ou moins, cela n'apparaît pas entraîner un nombre significatif de risques commerciaux ou systématiques. Les producteurs peuvent maintenir des inventaires de grumes sur le Marché de Vancouver sans accroître le risque financier de leurs entreprises.

[Traduit par la rédaction]

Introduction

The Vancouver Log Market (VLM) describes the selling, buying, and trading of logs on the coast of British Columbia. This informal institution does not possess a single physical location. Market activity is centred in the Howe Sound – Fraser River area but transactions take place over the entire coast of British Columbia. Log prices, however, are usually adjusted to reflect transportation costs to the Howe Sound – Fraser River area. In the last three decades, the share of total coastal harvest in British Columbia traded through the VLM has fluctuated between 14 and 30%, and, in 1988, represented 25% of the total or about 8×10^6 m^3 (Council of Forest Industries of British Columbia 1989).

The VLM plays an important role in the allocation of logs among various mills and in timber appraisals. For these reasons, most studies of the VLM focus on its allocative efficiency (Pearse et al. 1974; Pearse 1976) and its relationship with the provincial stumpage revenue (Council of Forest Industries of British Columbia 1989). The informational efficiency of this market has apparently never been explored.

Informational efficiency refers to the capacity of a market to process information rapidly related to expectations about future prices. Tests of the informational efficiency of markets seek to reject the hypothesis that all relevant information is reflected in current market prices.

When examining market efficiency, financial economists traditionally distinguish three categories of information. Markets are said to be weak-form efficient if they correctly incorporate all information obtainable by studying historical prices, semistrong-form efficient if they reflect all publicly available information, and strong-form efficient if they account for both public and private information (Fama 1970). The information categories are nested so that rejection of weak-form efficiency implies rejection of semistrong- and strong-form efficiency as well. Empirical studies of markets for agricultural commodities (Holthausen and Hughes 1978), logs in the U.S. Pacific Northwest (Olsen and Terpstra 1981), sawtimber stumpage in the U.S. South (Washburn and Binkley 1990) and precious metals (Solt and Swanson 1981) generally support weak-form efficiency. Empirical analyses of markets for financial assets have also consistently supported weak-form efficiency (Malkiel 1985) and semistrong-form efficiency (Malkiel 1989), although some contrary evidence has recently emerged (Fama 1991).

What about the VLM? Tests of informational efficiency obviously require a model of price expectations. Because logs do not change in physical dimensions as they are stored (at least for short periods of time), storage costs and expectations about future prices determine the expected returns to holding logs. Equilibrium in capital markets requires that expected returns for an asset be related to that asset's level of risk. Analysts commonly use the capital asset pricing model (CAPM) (Sharpe 1964; Lintner 1965) to model the market risk of an asset and therefore the price expectations held by the market for that asset. Any systematic patterns in the historical deviations from these expectations indicate that the market is not weak-form efficient.

The first section below reviews the CAPM for spot commodity prices and derives the relevant tests for weak-form market efficiency. The second section uses this model to test the informational efficiency of the VLM for the most important species transacted in the market. As a by-product

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of this analysis, we obtain some interesting information about the market or systematic financial risk of holding logs. The final section concludes that for quarterly or annual holding periods the VLM generally appears to be weak-form informationally efficient; that few gains can be made by speculating in this market using technical analysis of past price movements; and that producers can hold log inventories for short periods (up to 3 months) without increasing the financial risk of their enterprises. Explanations for the failure of the monthly series to pass the tests of informational efficiency require further exploration.

A model of informational efficient log market

Examining informational efficiency involves studying the intertemporal deviations of asset returns from their expected values. As a consequence, tests of information efficiency begin with a model of asset returns and asset prices. The CAPM is the most widely used of these, although it is not without criticism (Roll 1977; Ross 1978). The CAPM states

[1] $E_t r_{i,t} - r_{rft} = \alpha_i + \beta_i (E_t m_t - r_{rft})$

where

$E_t r_{i,t}$ is the expected return on asset i in period t

r_{rft} is the risk-free rate of return during period t

$E_t m_t$ is the expected rate of return on the overall market portfolio during period t

β_i is the risk coefficient of asset i

α_i is the "excess return" for asset i

If an investor can diversify her portfolio, the slope coefficient β_i in the CAPM indicates the systematic or undiversifiable risk of holding asset i. An asset with the same financial risk as the market as a whole has a β_i equal to one; the smaller the coefficient, the less the financial risk. An asset with β_i equal to zero carries no systematic financial risk. The parameter α_i measures the excess returns of the asset (i.e., the returns for the asset that are not due to the asset's level of risk). For capital markets to be in equilibrium the α_i's should all be zero. Deviations from zero indicate that the assets are mispriced, or that certain costs (e.g., transaction costs) or benefits (e.g., intangible values or risk factors not priced by the CAPM) have been omitted from the analysis.

To estimate this model, we calculated the rates of returns on holding logs as the logarithm of the ratio of successive prices, with the costs of storing logs (including ground lease fees, stickers and gear, deterioration, and insurance premiums) for one period subtracted from the second-period price:

[2] $$r_{i,\,t} = \ln\left(\frac{p_{i,\,t+1} - c_{i,\,t}}{p_{i,\,t}}\right)$$

where

$p_{i,t}$ is the price per cubic metre of log type i during period t;

$c_{i,t}$ is the estimated storage costs per cubic metre of log type i during period t.[2]

The information set for our tests of weak-form efficiency consists of past departures from equilibrium rates of return on holding logs.

Because expected returns cannot be observed, the model must be estimated from *ex post* data. Following Jensen (1969) we regress historical risk premia for asset i on contemporary risk premia for the market portfolio:

[3] $r_{i,t} - r_{rft} = \alpha_i + \beta_i (m_t - r_{rft}) + \varepsilon_{i,t}$

where the $\varepsilon_{i,t}$ are the ordinary least squares residuals: $E[\varepsilon_{it}] = 0$, and $\text{cov}(\varepsilon_{i,t}\varepsilon_{i,t+j}) = 0$ for all $j = 0$. Weak-form efficiency requires that departures of actual $(r_{i,t} - r_{rft})$ from equilibrium $(\alpha_i + \beta_i (m_t - r_{rft}))$ rates of return be white noise.

The return on the market portfolio, m_t was obtained from the Centre for Research on Security Prices monthly composite index of stocks on the New York Stock Exchange. Realized returns on the riskless asset, r_{rft}, were determined from monthly data published by the U.S. Federal Reserve Board. The monthly indices were averaged to obtain quarterly and annual indices. For example, quarterly market portfolio returns were calculated as the logarithm of the ratio of successive quarterly market values, which are the arithmetic means of relevant 3-month market values.

A testable implication of eq. 3 is that departures from equilibrium rates of return are serially independent. That is, past departures from equilibrium prices cannot be used to identify future departures. A finding of serial dependence is cause to reject a joint hypothesis that the VLM is efficient and that equilibrium rates of log return conform to the CAPM (Fama 1976). In short, we reject weak-form informational efficiency of the market if the residuals from the CAPM are not serially independent.

Following Washburn and Binkley (1990), we calculate two measures of serial dependence. The first, more common, measure is the autocorrelation function of residual errors $\varepsilon_{i,t}$ in eq. 3. If the residual errors are serially independent, the hypothesis is that the log market is weak-form efficient cannot be rejected and weak-form information cannot be used to identify departures of log return from equilibrium levels.

However, such parametric tests of serial dependence are comparatively weak evidence: they can reject the market-efficiency hypothesis either because the market is indeed inefficient or because of incorrect parameterization of the underlying stochastic process. In the present case, if the residuals are not normally distributed, the standard hypothesis tests on the serial correlation coefficients may be misleading. Thus, the normality of the deviations from expected returns must be examined.

To do so, we calculate the skewness and kurtosis of each series and then compare them with the values expected for a normal variant using a χ^2 goodness of fit test (Klein 1974, p. 372). In the cases where this test rejects normality, we use a nonparametric turning point test (Kendall and Stuart 1967, pp. 351–354). For a series of n uncorrelated random variables, the expected number of turning points in the series is 0.667 $(n - 2)$. Positive deviations from this expected number indicate negative serial dependence.

[2]The B.C. Ministry of Forestry provided estimates of log-storage costs in the VLM for 1990. We assumed that these costs were constant in real terms, and obtained annual estimates of storage costs by deflating the 1990 value using the annual Canadian all-products consumer price index. The storage cost for a particular year was used to represent the storage cost for each month in that year. For the average holding periods, storage costs apparently comprise less than 2% of the log value.

TABLE 1. Estimated CAPM coefficients for five log species transacted in the VLM from January 1971 to December 1990

Species	α_i	t	β_i	t	R^2
		Monthly			
Balsam	−0.0612 (0.0113)*	−5.4369	0.2747 (0.1289)*	2.1315	0.02
Cedar[a]	−0.0561 (0.0114)*	−4.9047	0.3174 (0.1310)*	2.4237	0.03
Douglas-fir[b]	−0.0685 (0.0191)*	−3.5942	0.1346 (0.2181)	0.6173	0.01
Hemlock	−0.0648 (0.0118)*	−5.4858	0.2410 (0.1352)†	1.7827	0.01
Spruce[a]	−0.0654 (0.0406)	−1.6168	0.1330 (0.4644)	0.2865	0.00
		Quarterly			
Balsam	−0.0771 (0.0126)*	−6.1081	0.1390 (0.1143)	1.2161	0.02
Cedar	−0.0514 (0.0143)*	−3.6004	0.4482 (0.1292)*	3.4702	0.14
Douglas-fir[b]	−0.0651 (0.0146)*	−4.4541	0.2202 (0.1324)	1.6633	0.04
Hemlock	−0.0801 (0.0128)*	−6.2342	0.1501 (0.1163)	1.2904	0.02
Spruce	−0.0859 (0.0411)*	−2.0880	−0.3254 (0.3722)	−0.8741	0.01
		Annual			
Balsam	0.0179 (0.0905)	0.1982	1.8315 (1.2404)	1.4766	0.12
Cedar	0.0966 (0.1260)	0.7670	2.5516 (1.7265)	1.4779	0.12
Douglas-fir	0.0134 (0.0800)	0.1677	1.4209 (1.0973)	1.2950	0.10
Hemlock	0.0072 (0.0867)	0.0838	1.8453 (1.1880)	1.5533	0.13
Spruce	0.1861 (0.1853)	1.0045	3.0966 (2.5400)	1.2191	0.09

NOTE: Numbers in parentheses are standard errors of regression coefficients.
[a]Weak-form efficiency rejected on the basis of turning point test.
[b]Weak-form efficiency rejected on the basis of serial correlation test.
*Significant at 5% level.
†Significant at the 10% level.

Reporting log prices as averages of prices observed throughout the measurement interval (e.g., the average price during each month) rather than values at a particular point in time (e.g., the price on 1st day of every month) induces spurious positive dependence in the rate of price change between successive periods. Working (1960) and Washburn and Binkley (1990) demonstrate that when rates of change are calculated from averages of random values at equally spaced intervals within a period, the induced serial correlation at the first lag is 0.25 and with no induced correlation at the second and all subsequent lags. Thus, in the parametric test, the null hypotheses of market efficiency is a serial correlation coefficient of 0.25 at the first lag and zero at all subsequent lags. For the nonparametric test, period averaging reduces the expected number of turning points to 0.604 $(n - 2)$ (Washburn and Binkley 1990).

Results for the Vancouver Log Market

We obtained historical price series (monthly, quarterly, and annual) from 1971 to 1991 from the British Columbia Council of Forest Industries for five major log species sold in the VLM. The five, true firs (collectively called "balsam" in British Columbia), cedar, Douglas-fir, hemlock, and spruce, accounted for 14.7, 29.9, 12.4, 34.1 and 3.2%, respectively, of the total volume transacted in the market in 1988, and collectively comprised 94.3% (Sirkia 1989). The Council of Forest Industries acquires reports of all log transactions in the VLM according to species, grade and value, and volume. At the end of each month, they compute the volume-weighted average price for each grade and species as total value for that grade or species divided by total volume. The Council of Forest Industries computes quarterly and annual prices in the same way.

To avoid the statistical or substantive artifacts of averaging across species and grades, it is preferable to analyze the data in its most disaggregate form. Unfortunately, the definitions of the log grades used in the VLM change from time to time. The most recent changes occurred in July 1990 and in August 1985. We therefore conduct two analyses. The first uses average prices for each of the five species volume-weighted across grades, and conducts the analysis over the entire 20-year times series. At the expense of losing detail on the individual grades, this analysis produces longer-term evidence on the informational efficiency of the VLM and the risk of holding logs, and provides enough observations to analyze annual holding periods. The second analysis covers only the 58 months between September 1985 and June 1990 where the data on individual grades are comparable. This analysis provides a more recent and detailed look at the market and avoids the loss of information associated with averaging prices across grades.

For each data set, we provide a single table that includes the CAPM results and notations explaining whether or not weak-form informational efficiency is rejected. If the χ^2 test fails to reject normality of the residuals from our estimates of eq. 3, we base the test of informational efficiency on the statistical significance of the lag-one serial correlation coefficient differing from 0.25. If the χ^2 test rejects normality of the residuals, then we use the nonparametric test. Tables giving the details of these tests comprise an appendix to this paper.

Grade-weighted average prices

Table 1 presents the α_i and β_i coefficients from the CAPM for the monthly, quarterly, and annual intervals (the t-statistics presented must be interpreted carefully in light of the non-normality of some of the distributions that are noted below). For the monthly interval, three of the five β_i's are small but statistically significantly greater than zero. The other two are not statistically different from zero. The α_i's are all negative, indicating that, after accounting for both storage costs and risks, holding logs generated lower than expected financial returns. This may reflect the "convenience yield" that logs afford sawmills in the inventory management and in meeting specific customers orders.

The results for quarterly and annual periods are roughly similar, with only the quarterly series for cedar showing any statistically significant level of systematic risk. The β_i's in annual series are all higher than those for the shorter term series, suggesting that holding a log in the VLM for 1 year is comparatively risky where the risk is low if the holding period is limited to a few months.

Three of the five monthly series fail to pass our test for informational efficiency. The plots of the autocorrelation functions show that the serial correlation generally persists for one to three lags, except in the case of spruce, which has a statistically significant correlation in the twelfth lag. Thus, studying the past behaviour of monthly log returns can help predict future departures from equilibrium rates of return for 1–3 months, and longer in the case of spruce.

For the quarterly data, the serial dependence persists only for Douglas-fir prices. Interestingly, the balsam fir prices show serial correlation in the quarterly data where they do not in the monthly data. None of the annual series fail to pass our tests for informational efficiency. This may be due to the smaller number of observations for those series, and the consequently lower precision of our estimates of the serial correlation coefficients.

Results for individual grades

Because the reported log prices are weighted each month by grade and by volume, we suspect changes in the overall quality of the log mix from month to month could contribute to the observed changes in the average log prices for each species. Such changes in the log mix violate the requirement of the CAPM that the asset be homogeneous through time. We can control for this effect by analyzing the data for individual grades.[3]

Table 2 presents the results for 19 grades of four species (four for balsam, six for cedar, five for Douglas-fir, and four for hemlock; spruce was dropped because it only accounts for some 3.2% of the total volume traded in the VLM). Taken together, these grades consistently represent more than 80% of the volume of the species traded in VLM.

The rules that describe these grades account for a large number of factors (e.g., size, weep, crook, placement and size of knots, shake, check, twist, eccentricity, insect and worm holes, rot, and conks) and cannot be easily summarized in a few lines. The key point for the analysis in this paper is that the specifications for an individual grade have remained constant throughout the period.

As with the grade-weighted average prices, the β_i's are generally small and few are statistically different from zero. As a consequence, there is not much market-related risk for holding logs in the VLM for one quarter or less. For the monthly data, the α_i's are again all negative, but rise or become statistically indistinguishable from zero in the quarterly analysis. For all except the lowest grades, monthly prices for both cedar and Douglas-fir prices again fail to pass the tests for informational efficiency. Unlike the grade-weighted average prices, all of the quarterly price series (except for cedar grade m) appear to be informationally efficient. We conclude that shifts in grade mix influence the quarterly results, but not the monthly ones.

Discussion and conclusions

The results of these tests for weak-form informational efficiency of the VLM depend on the time interval over which departures from equilibrium rate of return are measured. On annual and quarterly bases, departures from equilibrium rates are serially independent, indicating that the VLM is weak-form efficient. Weak-form information cannot be used to produce a better estimate of next year's or next quarter's log price than the current capitalized price. On the other hand, the monthly data from the VLM do not pass this test, so studying the previous departures from equilibrium return can help predict log returns a month in the future, and therefore next month's log prices.

Participants in the VLM apparently determine the holding period for individual log booms by weighing the need of an adequate log inventory for large coastal sawmills against the costs of holding inventory and the physical deterioration of logs if they are held in tidewater too long. Conversations of a few of the market participants suggest that typical holding periods for individual log booms range from 2 to 4 months. As a consequence, our quarterly results are probably the most representative of actual market transactions.

For quarterly intervals, holding logs in the VLM appears to generate little systematic risk. A firm can hold logs as part of its production inventory without contributing much to the company's overall systematic risk. Olsen and Terpstra (1981) and Olivotto (1987) reached similar conclusions for the Industrial Forestry Association log market in the U.S. Pacific Northwest.

Trading logs in the VLM does not generate returns in excess of those expected for the financial risk involved. In fact, the return to holding logs is inadequate to compensate for the financial risk of holding logs. This might be attributable to the convenience yield that the VLM provides: the market comprises a ready source of logs in inventory for processors, and log prices adjust to reflect this value.

The observed statistically significant negative correlation of prices on a monthly basis indicates that higher than expected prices in 1 month tend to be followed by lower than expected prices in the next month. In principle, firms could time purchases and sales of logs to take advantage of this technical information contained in the price series. However, we have not assessed the transactions cost for such a strategy, and therefore do not know if the trading gains would exceed these costs.

These results are generally consistent with Washburn and Binkley's (1990) findings for southern pine stumpage, but the same explanations do not seem to apply. They argue that the lack of weak-form efficiency in southern timber markets arises from the "friction in the market due to the time and cost involved in consummating timber sales" (p. 394). Timber sales typically require substantial efforts to consummate (identifying of willing sellers, marking timber-sale boundaries, cruising the time, developing the bid prospec-

[3]We also created eight monthly and quarterly price series from 1971 to August 1985 for the four species (balsam fir, cedar, Douglas-fir, and hemlock) by using a fixed-weight averaging process, where the weight is the averaged percentage of grades in each species over the entire period. The results from this approach are consistent with those in this section.

TABLE 2. Estimated CAPM coefficients for 19 grades of four log species transacted in the VLM from September 1985 to June 1990

Species	Grade	α_i	t	β_i	t	R^2
Monthly						
Balsam[a]	h	−0.0648 (0.0142)*	−4.5664	0.9860 (0.1881)	0.5224	0.01
Balsam[a]	i	−0.0715 (0.0105)*	−6.8030	−0.0027 (0.1399)	0.0190	0.00
Balsam	j	−0.0852 (0.0156)*	−5.4664	−0.1123 (0.2075)	−0.5413	0.01
Balsam	x	−0.0773 (0.0157)*	−4.9200	0.1066 (0.2092)	0.5095	0.01
Cedar[a]	h	−0.0696 (0.0118)*	−5.8931	0.0153 (0.1571)	0.0975	0.01
Cedar[a]	i	0.1986 (0.0267)*	7.4388	0.3597 (0.3553)	1.0124	0.02
Cedar[b]	j	−0.0749 (0.0218)*	−3.4419	0.1654 (0.2897)	0.5712	0.01
Cedar[a]	k	−0.0835 (0.0197)*	−4.2399	−0.1673 (0.2627)	−0.6371	0.01
Cedar[a]	l	−0.0097 (0.0178)*	−4.5424	−0.1197 (0.2372)	−0.5044	0.01
Cedar[a]	m	−0.0916 (0.0311)*	−2.9404	−0.0963 (0.4144)	−0.2325	0.00
Douglas-fir[a]	c	−0.0690 (0.0136)*	−5.0668	0.0241 (0.1812)	0.1330	0.00
Douglas-fir[a]	h	−0.0637 (0.0143)*	−4.4513	0.2019 (0.1905)	1.0594	0.02
Douglas-fir[a]	i	0.0541 (0.0120)*	−4.5076	0.3389 (0.1597)	2.1228	0.08
Douglas-fir[a]	j	−0.0662 (0.0136)*	−4.8846	0.1853 (0.1803)	1.0277	0.02
Douglas-fir[a]	x	0.0843 (0.0592)	−1.4240	0.1232 (0.7880)	0.1564	0.00
Hemlock[a]	h	0.0650 (0.0169)*	−3.8360	0.1223 (0.2255)	0.5421	0.01
Hemlock	i	−0.2311 (0.2107)	−1.0968	−2.2725 (2.8045)	−0.8103	0.01
Hemlock	j	−0.0847 (0.0102)*	−8.2961	−0.1924 (0.1358)	−1.4168	0.04
Hemlock	x	−0.0754 (0.0143)*	−5.2757	0.0930 (0.9026)	0.4890	0.01
Quarterly						
Balsam	h	−0.0656 (0.0314)*	−2.0890	0.1023 (0.4946)	0.2069	0.00
Balsam	i	−0.0585 (0.0338)[†]	−1.7310	0.3321 (0.5327)	0.6234	0.02
Balsam	j	−0.0674 (0.0503)	−1.3411	0.3780 (0.7919)	.4773	0.01
Balsam	x	−0.0547 (0.0728)	−0.7518	0.8158 (1.1468)	0.7113	0.03
Cedar	h	−0.0098 (0.0403)	−0.2433	1.1990 (0.6343)[†]	1.8902	0.18
Cedar	i	0.2925 (0.0586)*	4.9878	2.0548 (0.9240)*	2.2238	0.24
Cedar	j	−0.0214 (0.0410)	−0.5214	1.2185 (0.6459)[†]	1.8866	0.18
Cedar	k	−0.0409 (0.0571)	−0.7162	0.6715 (0.8994)	0.7461	0.03
Cedar	l	−0.0411 (0.0575)	−0.7150	0.7316 (0.9055)	0.8080	0.04
Cedar[a]	m	−0.0523 (0.0714)	−0.7328	0.9957 (1.1250)	0.8851	0.05
Douglas-fir	c	−0.0744 (0.0301)*	−2.4698	−0.0366 (0.4745)	−0.0772	0.00
Douglas-fir	i	−0.0621 (0.0281)*	−2.2103	0.2562 (0.4426)	0.5789	0.02
Douglas-fir	h	−0.0612 (0.0297)	−2.0609	0.2124 (0.0467)	0.4542	0.01
Douglas-fir	j	−0.0447 (0.0399)	−1.1196	0.7315 (0.6290)	1.1629	0.08
Douglas-fir	x	0.0088 (0.1245)	0.0708	2.2605 (1.9615)	1.1519	0.08
Hemlock	h	−0.0573 (0.0352)	−1.6287	0.3319 (0.5547)	0.5984	0.02
Hemlock	i	−0.1174 (0.0726)	−1.6175	−0.7768 (1.1440)	−0.6790	0.03
Hemlock	j	−0.0688 (0.0404)[†]	−1.7055	0.2141 (0.6360)	0.3366	0.01
Hemlock	x	−0.0507 (0.0717)	−0.7062	0.8306 (1.1304)	0.7348	0.03

NOTE: Numbers in parentheses are standard errors of regression coefficients.
[a]Weak-form efficiency rejected on the basis of serial correlation test.
[b]Weak-form efficiency rejected on the basis of turning point test.
*Significant at the 5% level.
[†]Significant at the 10% level.

tus, and auctioning the timber), so their explanation may be reasonable for that market. For logs held in rivers or tidewater in grade-sorted booms where transportation costs are low, the "market friction" explanation is much more difficult to sustain.

The estimated CAPM β's for the VLM appear to depend on the holding period. In contrast, Lee (1976) argues that the systematic risk of an investment should be independent of the investment horizon. Although the CAPM β's tend to increase from the monthly to quarterly to annual time intervals, the most significant increase occurs between the quarterly and annual time periods. This increase may simply reflect the fact that very few firms hold logs for that long a period, so the annual data do not describe any actual market behaviour.

Finally, Haight and Holmes (1991) argue that averaging reported monthly prices across a quarter to estimate the spot price for the quarter might mask serial correlation in the underlying spot prices. However, their analysis is based on monthly prices that are themselves averages of spot prices throughout the month, and therefore must be considered suggestive rather than definitive. Because all of the log and timber price reports available in North America reflect period-averaged prices, this problem remains an important open question for timber market analysis and the related problem of log and timber trading strategies.

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Appendix: Details of serial correlation, normality, and turning point test for the two data sets

TABLE A1. Serial correlation coefficients for five log species transacted in the VLM from January 1971 to December 1990

	Lag					
Species	1	2	3	4	8	12
Monthly						
Balsam	−0.29*	−0.11	0.11	0.08		0.12
Cedar	−0.30*	0.06	0.16*	−0.09		0.00
Douglas-fir	−0.54*	0.16*	−0.06	0.03		−0.07
Hemlock	−0.29*	−0.09	0.01	0.24		0.12
Spruce	0.45*	0.14*	−0.18*	−0.03		0.28*
Quarterly						
Balsam	0.08	0.19	0.12	0.03	−0.08	
Cedar	0.26	0.04	0.11	0.07	−0.02	
Douglas-fir	−0.24*	0.18	−0.09	0.14	0.05	
Hemlock	0.11	0.13	0.10	0.08	−0.09	
Spruce	−0.32*	−0.01	−0.07	0.32*	0.11	
Annual						
Balsam	0.20	−0.21	−0.03	−0.44		
Cedar	0.04	−0.34	−0.18	0.13		
Douglas-fir	−0.09	−0.08	−0.20	−0.16		
Hemlock	0.15	−0.20	0.03	−0.43		
Spruce	−0.11	−0.28	0.04	−0.41		

*The correlation coefficient is 2 SE from the expected value (0.25 for the first lag and 0.13 for the others).

TABLE A2. Normality test for regression residuals from January 1971 to December 1990

Residuals	Skewness	Excess kurtosis	χ^2
Monthly			
Balsam	−0.6198	1.4632	35.0902**
Cedar	0.2116	14.1423	36.8605**
Douglas-fir	−0.1784	1.3221	18.5632
Hemlock	−0.2193	2.8809	47.7326**
Spruce	0.6415	4.3887	53.6284**
Quarterly			
Balsam	−0.7159	1.6202	10.1004**
Cedar	−0.3098	0.2769	2.3138
Douglas-fir	−0.1453	−0.2946	0.6070
Hemlock	−0.4644	0.5254	5.4622
Spruce	−1.3948	5.5813	12.7620**
Annual			
Balsam	1.2984	2.9777	3.7349
Cedar	0.1883	−0.3735	1.7965
Douglas-fir	2.0264	6.0940	5.1167
Hemlock	0.7413	1.2079	2.3606
Spruce	0.8455	0.2276	3.4963

**Significant at the 1% level.

TABLE A3. Turning points test for regression residuals from January 1971 to December 1990

Residuals	Expected	Observed
Monthly		
Balsam	158.0	146
Cedar	158.0	127*
Hemlock	158.0	162
Spruce	158.0	138*
Quarterly		
Balsam	51.3	36*
Spruce	51.3	41

*The observed number of turning points is 2 SE from the expected number.

TABLE A4. Serial correlation coefficients for 19 grades of four log species in the VLM from September 1985 to June 1990

		Lag			
Species	Grade	1	2	3	4
Monthly					
Balsam	h	−0.32*	0.02	0.15	−0.03
Balsam	i	−0.09*	0.15	0.14	0.01
Balsam	j	0.03	0.07	0.16	0.02
Balsam	x	0.26	0.14	0.17	−0.03
Cedar	h	−0.14*	0.23	0.16	0.03
Cedar	i	0.29	0.18	0.26	0.18
Cedar	j	−0.07*	−0.06	0.11	0.01
Cedar	k	−0.34*	0.21	−0.05	0.06
Cedar	l	−0.24*	0.26	−0.11	0.08
Cedar	m	−0.35*	0.24	−0.15	0.11
Douglas-fir	c	−0.35*	0.03	0.16	−0.23
Douglas-fir	h	−0.34*	0.06	0.17	−0.22
Douglas-fir	i	−0.20*	−0.20	0.27	−0.15
Douglas-fir	j	−0.18*	0.08	−0.00	−0.09
Douglas-fir	x	−0.45*	−0.08	0.22	−0.14
Hemlock	h	−0.18*	−0.10	0.29*	−0.13
Hemlock	i	0.45	−0.01	0.01	−0.02
Hemlock	j	−0.01	0.23	0.04	−0.03
Hemlock	x	0.21	0.23	0.13	−0.12
Quarterly					
Balsam	h	0.33	0.20	0.03	−0.17
Balsam	i	0.38	0.10	−0.08	−0.22
Balsam	j	0.08	−0.42	−0.12	−0.03
Balsam	x	0.13	−0.43	−0.25	−0.11
Cedar	h	0.04	−0.18	−0.11	0.04
Cedar	i	0.27	0.16	0.18	−0.03
Cedar	j	0.17	−0.11	−0.08	−0.10
Cedar	k	−0.12	−0.44	0.05	0.19
Cedar	l	−0.16	−0.44	0.10	0.24
Cedar	m	−0.30*	0.11	0.06	0.18
Douglas-fir	c	−0.09	−0.13	−0.09	0.08
Douglas-fir	h	0.11	−0.27	−0.20	−0.19
Douglas-fir	i	0.09	−0.24	−0.17	−0.25
Douglas-fir	j	0.19	−0.41	−0.17	−0.28
Douglas-fir	x	−0.25*	−0.24	0.06	−0.05
Hemlock	h	0.31	0.05	0.04	−0.02
Hemlock	i	−0.27*	0.15	−0.16	0.07
Hemlock	j	0.12	0.50*	−0.17	0.02
Hemlock	x	0.12	−0.47	−0.21	−0.08

*The correlation coefficient is 2 SE from the expected values (0.25 for the first lag, 0.00 for all others).

TABLE A5. Normality test of regression residuals for 19 grades of four log species in the VLM from September 1985 to June 1990

Residuals				
Species	Grade	Skewness	Excess kurtosis	χ^2
Monthly				
Balsam	h	−0.0039	4.3939	4.8283
Balsam	i	0.1965	0.0979	2.7218
Balsam	j	−1.6647	8.3990	8.6275
Balsam	x	−0.3894	6.0883	5.1415
Cedar	h	0.0769	0.7148	3.5036
Cedar	i	−2.6659	14.8667	9.8361*
Cedar	j	−3.3801	20.7131	13.6807**
Cedar	k	0.0079	1.6361	2.4755
Cedar	l	−0.0024	2.1314	5.4247
Cedar	m	−0.1297	2.6775	14.8961**
Douglas-fir	c	−0.1620	0.0179	1.8939
Douglas-fir	h	−0.0984	1.1706	4.3096
Douglas-fir	i	0.3503	0.2365	2.4708
Douglas-fir	j	0.2906	1.4548	6.3680*
Douglas-fir	x	0.5089	12.1665	10.8822**
Hemlock	h	−0.2584	2.4185	6.0494*
Hemlock	i	−3.1123	31.7903	38.8821**
Hemlock	j	0.3278	3.1051	18.9002**
Hemlock	x	0.6113	2.0129	2.4755
Quarterly				
Balsam	h	0.5481	−0.6574	2.8004
Balsam	i	0.5495	−0.1734	2.7583
Balsam	j	0.0290	−1.0527	2.1493
Balsam	x	−0.0434	−0.4224	1.1504
Cedar	h	−0.2135	0.0685	1.4709
Cedar	i	−0.8279	1.7010	2.7583
Cedar	j	−0.5268	0.9733	3.7349
Cedar	k	−0.4958	0.2208	3.7349
Cedar	l	−0.6085	0.3547	2.7583
Cedar	m	0.0968	0.3002	3.0117
Douglas-fir	c	−0.6552	0.1829	1.7965
Douglas-fir	h	0.0664	−0.6039	1.1504
Douglas-fir	i	0.4745	−0.3325	2.3656
Douglas-fir	j	0.1626	−1.3582	3.5459
Douglas-fir	x	0.1860	2.8993	8.0342*
Hemlock	h	0.5042	1.6393	3.6430
Hemlock	i	−0.2432	4.0318	7.7087*
Hemlock	j	0.3104	−1.0149	2.1493
Hemlock	x	0.1724	−0.5789	1.8958

*Significant at the 5% level.
**Significant at the 1% level.

Table A6. Turning points test for 19 grades for four log species in the VLM from September 1985 to June 1990

Species	Grade	Expected	Observed
Monthly			
Balsam	i	37.3	33
Cedar	i	37.3	24*
Cedar	j	37.3	29*
Cedar	m	37.3	42
Douglas-fir	j	37.3	29*
Douglas-fir	x	37.3	41
Hemlock	h	37.3	35
Hemlock	i	37.3	32
Hemlock	j	37.3	30
Quarterly			
Douglas-fir	x	11.3	8
Hemlock	i	11.3	9

*The observed number of turning points is 2 SE from the expected number.