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# Price dynamics in the New Zealand log market

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## Abstract

In this article the monthly prices of logs in four New Zealand regions were examined for their stochastic properties. Of interest was whether log prices can be considered stationary or non-stationary processes. Tests which had both stationary and non-stationary null hypotheses were employed. Results support a non-stationary price process for virtually all log grades and regions. This has implications for the timing of harvesting and the valuation of timberland in the country as they suggest reserve pricing rules will yield little gain for timberland owners.

Keywords: log market; option pricing; time series; stochastic prices; timber valuation

## Introduction

The price dynamics of markets has been of great interest to scholars and investors alike. Taking centre stage in these investigations has been the question of whether market prices follow a random walk, which is an example of a non-stationary process. This issue has been a matter of inquiry generally for two related reasons. Firstly, economic theory predicts that "informationally efficient" markets follow a random walk (Fama 1970).[2] Markets are said to be weak-form efficient if they correctly incorporate all information obtainable from past prices, in such a case there is nothing to gain from analysing past prices, for they do not help predict future prices (Binkley *et al.* 2001). Secondly, the pricing of options, depends heavily on the anticipated future price path, with notable pricing models such as Black Scholes (Black and Scholes 1973) relying on geometric Brownian motion which occurs when the natural log of a series follows a random walk in continuous time. There have been volumes of literature produced on the subject, particularly in stock markets. This research has been rather mixed however, with ample studies both supporting and rejecting the efficiency of stock markets (see for example Malkiel 2004; Lo and MacKinlay 2001).

The motivation for study and prior research results are no different in forestry. Log and standing timber (stumpage) markets tend to involve significant transaction costs and are often not characterised by continuous trading; this seems to weigh against the market efficiency hypothesis (Washburn and Binkley 1990, Clark and Reed 1989). Furthermore, determining a reserve price in the timing of timber harvesting is very sensitive to the stochastic price of the timber (Yin and Newman 1995; Haight and Holmes 1991; Gong and Lofgren 2007).[3] When prices follow a random walk, the current price is the best predictor of future prices so the gains from adaptive management are either very small or zero. Conversely, if prices can be considered as random draws from a distribution around a stationary mean or exhibit mean reversion, the potential gains from following a reserve pricing strategy are significant.[4] Plantinga (1998) shows that these potential gains are equivalent to the option value of holding timberland, with forestland located in markets that have prices which follow a random walk generating little to no option value and forestland in areas where prices are stationary, mean-reverting processes generating large option value.[5]

Econometric tests on prices in forestry markets to date have also produced conflicting results. Early studies tended to support the random-walk hypothesis and hence market efficiency, but results varied depending on whether monthly or quarterly data was used (Washburn and Binkley 1990, Haight and Holmes 1991). Subsequent studies by Yin and Newman (1996) supported stationary timber prices, yet more recent research has shown that these results are not invariant to the testing procedure (Prestemon 2003).

Theoretical appeals also occur in the literature. McGough *et al.* (2004) demonstrate that a timber market containing agents with rational expectations may evolve according to a stationary autoregressive moving average price process and Insey and Rollins (2005) suggest that timber prices, like most commodities, should eventually

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[2] *The idea of a random walk will be developed further later. However, a good basic definition is provided by Stock and Watson (2003) "The basic idea of a random walk is that the value of the series tomorrow is its value today, plus an unpredictable change".*

[3] *Unlike the Faustmann model where the optimum rotation age is fixed and prices are assumed to be constant, under a reserve pricing strategy the optimum rotation age will vary depending on price fluctuations. At a given age, if realized prices are above one's reserve price then it is optimum to harvest (this is also sometimes referred to as adaptive management). The appropriate reserve price will depend on the anticipated future price process. Also, in general, reserve prices tend to decrease with stand age.*

[4] *See Binkley et al. (2001) for a good discussion about the difference between random walks and mean reverting series, which also contains easy to follow illustrations.*

[5] *The option value will also depend on the variance of the price series.*

[6] *Although this argument is debatable, as long run marginal costs could also be stochastic, varying according to input prices and technology.*

revert to some mean, reflecting long run marginal costs.[6]

The purpose of this paper is to discover the price process of New Zealand's log market, a market which to date has not been tested in spite of being made up of an active group of buyers and sellers and located in a country which has been of considerable interest to timberland investors globally. Consequently, this will help to inform practitioners of appropriate reserve price strategies and the potential option value associated with forestland in the country. To do so, we test six log grades across four regional log markets for stationarity. The next section provides an overview of the testing methodology. Coming after this is some background about the data studied, followed by the results of the time series tests. A brief discussion and our conclusions ensue in the final section.

## Methodology

A price process is said to be weakly stationary if its mean and variance are constant over time and the value of the covariance between two time periods depends only on the distance or lag between the two periods and not the actual time when the covariance is computed (Gujarati 1995). A series could be non-stationary however simply because it exhibits a trend. In such a case, the series could be made stationary by a de-trending procedure (known as a trend stationary series). Furthermore, series that have unit roots (this concept is discussed further below) can be made stationary by differencing (known as a difference stationary series). The number of times a series needs to be differenced before it becomes stationary tells of its order of integration (Stock and Watson 2003). For example, if a non-stationary series is differenced once and it becomes stationary it is said to be integrated of order one, which is usually denoted I(1).

### *Tests for I stationarity*

The most popular test for non-stationarity has been unit root testing. Perhaps, foremost among these is the Dickey Fuller (DF) test. The DF procedure is based on the following simple AR(1) model:

$$P_t = \rho P_{t-1} + v_t \qquad (1)$$

where $P_t$ is the natural log of the price series, $P_{t-1}$ is the lag of the natural log of the price series, ρ is a parameter to be estimated, and $v_t$ is a disturbance term assumed to be independent and normally distributed with mean zero. The focus of the DF test is on the parameter ρ. The null hypothesis of the test is that ρ equals one, this is framed against the alternative that ρ is less than one and therefore is a stationary mean reverting process (Prestemon 2003).[7] If the null hypothesis cannot be rejected, then the series is said to have a 'unit root' and behaves as a random walk.

[7] *This test is a one sided test. p greater than one is usually ruled out as this would be an explosive series*

Standard t tests do not apply however, as under the null hypothesis the distribution of the t statistic is non-normal even in large samples (Stock and Watson 2003). Dickey and Fuller (1979) have generated corrected critical values to carry out the test.

The DF test is also often modified for data series that persistently grow upwards are downwards. This is done as follows:

$$P_t = \mu + \beta t + \rho P_{t-1} + v_t \qquad (2)$$

Where μ is a constant term, and *t* is the deterministic trend variable. The null hypothesis of the test is still focused on ρ and whether it is equal to one (i.e. a unit root). However, by including the trend term *(t)* the alternative hypothesis is now that the series is stationary around a deterministic trend. Furthermore, the inclusion of the constant term μ allows the series to be a random walk with a drift, also known as a stochastic trend (Stock and Watson 2003).

The DF testing framework outlined above is not without problems however. The most notable problem has been under-specification of the autocorrelation process (Prestemon 2003). This under specification causes serial correlation in the disturbance term ($v_t$) and makes the DF test biased. To accommodate serial correlation, Said and Dickey (1984) amended the testing framework.[8] This framework is known as the augmented Dickey Fuller (ADF) test.

Under the ADF test one is still interested in the parameter (ρ). But equation 1 or 2 is augmented with additional lags until the serial correlation disappears. The test is usually performed with differenced data and amounts to:

$$\Delta P_t = \mu + \beta t + \delta P_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta P_{t-i} + v_t \qquad (3)$$

Where Δ is the first difference operator; *m* is the number of lagged differences and δ is equal to (*p*-1). The test involves the parameter δ and whether it is significantly different than zero, which is equivalent to testing for a unit root (Gujarati 1995).

One of the central issues with the ADF procedure is how many lagged difference terms to include. Several 'information criterion' are typically employed, the most popular ones being the Schwarz information criterion (SIC) and the Akaike information criterion (AIC). Each has its downsides, the SIC often chooses too few lags and the AIC is not consistent (Stock and Watson 2003). Ng and Perron (2001) developed a modified Akaike information criterion (MAIC) which has shown to have the best size and power among the procedures so it was chosen as our chief lag selector.[9]

[8] *Another way of handling serial correlation is the Phillips and Perron test (1988).*

[9] *The power of a statistical test is the probability that the test correctly rejects the null hypothesis when the alternative is true. The size of a statistical test is the probability the test incorrectly rejects the null hypothesis when the null is true (Stock and Watson 2003).*

Another problem with both the DF and ADF test is its low power, particularly when $\rho$ is very close to 1. Elliot *et al.* (1996) developed and tested an alternate procedure which has shown to have higher power than the standard DF or ADF test. Essentially the procedure is the same as the DF or ADF test, except prior to the test, the time series is transformed by generalized least squares (GLS), as such the test has come to be known as DF-GLS (Stock and Watson 2003).

### *Testing for I stationarity*

A different way to deal with the problems associated with the DF tests are to instead have the null hypothesis be a stationary I(0) process. To accommodate such a hypothesis, the most commonly used procedure is the one developed by Kwiatkowski, Phillips, Schmidt, and Shin (1992), which is termed accordingly, the KPSS test. However, the KPSS test also has issues with low power. Hobijn *et al.* (1998) have shown that the properties (size and power) of the KPSS test - particularly in smaller samples - can be greatly improved by employing an automatic bandwidth procedure and by using the quadratic spectrum kernel in the estimate of the series variance. Given these improved statistical properties, this method was employed in our empirical testing.

### *Other orders of integration*

It is important to perform both a DF type test and a KPSS test for other reasons as well. For rejection of the null hypothesis under either framework does not automatically mean acceptance of the other. Indeed, it is possible for both of the null hypotheses to be rejected. In such a case, the time series are said to be fractionally integrated and exhibit long memory (Lee and Schmidt 1996). Furthermore, higher orders of integration are possible. As mentioned earlier, the level of integration is related to the number of times it has to be differenced in order to become stationary. Consequently, even if one fails to reject the hypothesis of a unit root, it is useful to supplement the analysis by examining the stochastic properties of the differenced data. If one takes the first difference of a non-stationary series and it becomes stationary, then one can usually safely rule out higher orders of integration (Stock and Watson 2003).

## Data

We utilised the reporting agency Agri-Fax (http://www.agri-fax.co.nz/forestry.cfm) for log market information. Agri-Fax separates the log market in New Zealand into four geographic zones for price reporting purposes. These zones are: 1) Northern South Island (NSI), 2) Southern South Island (SSI), 3) Northern North Island (NNI) and 4) Southern North Island (SNI). They also break the market for logs in New Zealand into two broad categories; export and domestic. The export market is primarily aimed at Asian markets, the biggest ones being China, South Korea, and Japan. In 2006 approximately 5 million cubic metres of logs were exported, fetching about 447 million New Zealand dollars (New Zealand Forest Owners Association 2006). We study two export grades in this paper; the first being A grade and the second being the KS grade. The specifications associated with these grades are shown in Table 1 as defined by Agri-Fax.

The domestic market on the other hand is segregated by Agri-Fax into pruned and unpruned logs. The pruned logs are demanded by local sawmills for clearwood sawnwood products or by veneer mills and the unpruned logs are made up of sawlogs and pulp logs. The sawlog grades are used principally for producing structural lumber for both domestic and international markets, but also find extensive use in packaging applications. Pulp logs are supplied to a few pulp and medium density fibreboard plants throughout the country (occasionally these logs are exported as well). In this study we analyse two grades of pruned logs (P1 and P2), one grade of sawlogs (S1/S2) and one pulp grade (pulp). The exact grade specifications are also given in Table 1 as specified by Agri-Fax.

Agri-Fax provided us with a time series of the prices for each of the log grades and regions mentioned above. They derive their data by surveying log purchasers (sawmills, log export brokers etc.) once a month. Seeing that the series are not an average of weekly prices, issues with data aggregation reported by Haight and Holmes (1991) are not a concern. With the exception of two series, monthly data over a twelve year period from January 1995 to December 2006 (144 observations) was obtained to be used for econometric testing. The price series for both pulp in the SSI and P1 in the SNI were shorter due to missing observations. Data for pulp prices in the SSI span from June 1997 to December 2006 (115 observations) and data for P1 prices in the SNI

*Table 1: Log grade specifications*

| | P1 | P2 | A | KS | S1/S2 | S3 | Pulp |
|---|---|---|---|---|---|---|---|
| Pruning | yes | yes | no | no | no | no | no |
| Minimum small end diameter (cm) | 40 | 35 | 30 | 20 | 40/30 | 22 | 10 |
| Maximum branch size (cm) | n/a | n/a | 12 | 10 | 6 | 6 | n/a |
| Minimum Length (m) | 4 | 4 | 12 | 4 | 4.95 to 6.1 | 3.7 to 4.6 | fixed/random |

*Source: Adapted from Agri-Fax (In March 2002 export grades were rationalised by Agri-Fax into Export Jap A/K, Long A, and Export K/J/C, short (US). Previously they were Jap A and K grades.)*

*Table 2: Dickey Fuller GLS test results. Null hypothesis unit root (i.e.: non-stationary series).*

| | | Region | | | |
|---|---|---|---|---|---|
| Grade | | NSI | SSI | NNI | SNI |
| P1 | DF statistic | 0.49 | 0.59 | -2.26† | 1.06 |
| | lags | 2 | 13 | 1 | 1 |
| P2 | DF statistic | 0.73 | 0.5 | -2.42† | -0.001 |
| | lags | 6 | 2 | 1 | 1 |
| A | DF statistic | -0.63 | -0.29 | -0.33 | -1.50† |
| | lags | 1 | 4 | 1 | 12 |
| KS | DF statistic | -1.58 | -0.82 | -1.56 | -1.60 |
| | lags | 1 | 9 | 1 | 1 |
| S1 / S2 | DF statistic | -0.92 | 0.23 | -0.17 | -0.25† |
| | lags | 2 | 1 | 3 | 1 |
| S3 | DF statistic | -0.28 | 0.15 | -0.83 | -0.67 |
| | lags | 13 | 1 | 1 | 1 |
| Pulp | DF statistic | -1.52† | -1.73† | -2.49** | 2.975*** |
| | lags | 1 | 2 | 2 | 1 |

Note: Unit root rejcted at *, 10%; **, 5%; ***, 1% as determined by response surface analysis of Elliot et al. (1996)

† Deterministic trend included if significant at 5% level

are over an eleven year time frame (132 observations).

Prices were deflated / inflated to June 2006 constant dollars using the New Zealand consumer price index (CPI). Seeing that the CPI is only reported on a quarterly basis, we derived a monthly CPI by assuming that changes in the CPI were spread evenly throughout the three months within the quarter.[10]

## Results

The DF-GLS tests (equation 3) were run in STATA 9.1. The lag length was selected by the MAIC; this selection procedure in most cases was consistent with the SIC. In those instances where the two criteria conflicted, conclusions pertaining to the null hypothesis of a unit root were unaffected. A deterministic trend ($t$) was included if significant at the 5% level, but again the presence of a deterministic trend term did not affect conclusions pertaining to the null hypothesis of a unit root. Results from these tests are summarized in Table 2.

[10] *Results discussed later are not sensitive to this assumption. As the same conclusions are drawn using raw nominal monthly data.*

*Table 3: KPSS test results. Null hypothesis stationary series.*

| | | Region | | | |
|---|---|---|---|---|---|
| **Grade** | | **NSI** | **SSI** | **NNI** | **SNI** |
| P1 | KPSS statistic | 2.36*** | 1.96*** | 0.49*** | 2.59*** |
| | bandwidth | 3 | 3 | 3 | 3 |
| P2 | KPSS statistic | 2.78*** | 2.42*** | 0.63*** | 2.29*** |
| | bandwidth | 3 | 3 | 3 | 3 |
| A | KPSS statistic | 2.16*** | 2.34*** | 3.1*** | 0.21** |
| | bandwidth | 3 | 3 | 3 | 3 |
| KS | KPSS statistic | 1.78*** | 1.65*** | 1.28*** | 1.32*** |
| | bandwidth | 3 | 3 | 3 | 3 |
| S1/S2 | KPSS statistic | 0.53** | 2.1*** | 2.63*** | 0.38*** |
| | bandwidth | 3 | 3 | 3 | 3 |
| S3 | KPSS statistic | 0.55** | 1.63*** | 2.27*** | 2.68*** |
| | bandwidth | 3 | 3 | 3 | 3 |
| Pulp | KPSS statistic | 0.36*** | 0.56** | 1.29*** | 0.44* |
| | bandwidth | 3 | 3 | 3 | 3 |

Note: Stationarity for the series rejected at *, 10%; **, 5%; and ***, 1% significance

With the exception of pulpwood on the North Island, the DF-GLS tests suggest that the hypothesis of non-stationarity, and market efficiency, cannot be rejected for all log grades and regions.

To complement the above, the KPSS test was also conducted with the bandwidth selected in a manner described by Hobijn *et al.* (1998). These results are presented in Table 3.

The KPSS test broadly rejects the null hypothesis of stationarity across all regions and log grades. The only possible exception to this being pulpwood in the Southern North Island, where stationarity was rejected only at the 10% level of significance. These results are very much consistent with the DF-GLS tests reported in Table 2 and combined they overwhelmingly support a non-stationary process for monthly log prices.

A final issue was whether or not the prices displayed any signs of higher orders of integration. As described earlier, if indeed the prices are integrated of order 1, then the first difference of the series should be stationary. To test for this the KPSS test was run on the first-differenced data. The results, shown in Table 4, suggest that higher orders of integration are generally absent and log prices in New Zealand are non-stationary I(1) processes.

*Table 4: KPSS test results on first differenced data. Null hypothesis stationary series.*

| Grade | | Region NSI | SSI | NNI | SNI |
|---|---|---|---|---|---|
| P1 | KPSS statistic | 0.11 | 0.15 | 0.07 | 0.15 |
| | bandwidth | 3 | 3 | 3 | 3 |
| P2 | KPSS statistic | 0.18 | 0.1 | 0.05 | 0.09 |
| | bandwidth | 3 | 3 | 3 | 3 |
| A | KPSS statistic | 0.27 | 0.26 | 0.1 | 0.03 |
| | bandwidth | 3 | 3 | 3 | 3 |
| KS | KPSS statistic | 0.1 | 0.08 | 0.12 | 0.12 |
| | bandwidth | 3 | 3 | 3 | 3 |
| S1 / S2 | KPSS statistic | 0.13 | 0.16 | 0.16 | 0.05 |
| | bandwidth | 3 | 3 | 3 | 3 |
| Pulp | KPSS statistic | 0.06 | 0.23 | 0.05 | 0.05 |
| | bandwidth | 3 | 2 | 3 | 3 |

Note: Stationarity for the series rejected at *, 10%; **, 5%; and ***, 1% significance

### Discussion and Conclusions

So what implications do the above results have for forest management in New Zealand? There are several. Firstly, and perhaps most importantly, they imply that the option value associated with timber assets that stem from price fluctuations, is either low or zero. This means that valuation methods that rely on discounted cash flow procedures for practical purposes are likely to be sufficient. Related to this, following reserve pricing rules based on deviations from historic means (Brazee and Mendelsohn 1988) are probably not applicable to the New Zealand situation. If forestry managers are keen on developing reserve pricing strategies, then rules that rely on non-stationarity are most appropriate (Thompson 1992, Reed 1993). Such rules however, often lead to management decisions that are very close to that derived under traditional Faustmann solutions.

Secondly, caution must be undertaken when relying on forecasting models that do not account for the non-stationary properties of the data. Forecasting prices by using autoregressive moving average methods (ARMA) or by fitting trends on un-differenced price series could have undesirable statistical properties. Furthermore, partial-equilibrium supply and demand models of the log market that have not properly accounted for the non-stationary aspects of the data are potentially spurious with biased estimates of elasticity, leading to incorrect inferences on the effects of changes in supply or demand (Song and Chang 2007).[11] Finally, policy analyses of various carbon schemes that assume mean reversion in timber prices, such as Guthrie and Kumareswaran (2003), are potentially flawed.

*Table 5: DF-GLS and KPSS test results on quarterly data.*

| Grade | DF-GLS | DF-GLS (with linear trend) | KPSS | Timeframe |
|---|---|---|---|---|
| A | -1.74[a] | -2.19 | 0.299 | 1973 q1 to 2001 q2 |
| A | -1.05 | -2.66 | 1.66*** | 1992 q1 to 2005 q4 |
| J | 0.11 | -1.96 | 1.33*** | 1994 q2 to 2005 q4 |
| K | -1.84 | -3.97*** | 1.55*** | 1992 q1 to 2005 q4 |
| P1 | 0.59 | -1.63 | 1.45*** | 1994 q2 to 2005 q4 |
| P2 | -0.49 | -2.15 | 1.76*** | 1992 q4 to 2005 q4 |
| S1 | -0.29 | -3.18* | 1.6*** | 1994 q3 to 2005 q4 |
| S2 | -0.87 | -3.79*** | 1.56*** | 1994 q3 to 2005 q4 |
| L1/L2 | -0.32 | -2.02 | 1.42*** | 1994 q3 to 2005 q4 |
| Domestic Pulp | -1.27 | -2.29 | 1.03*** | 1994 q3 to 2005 q4 |

Note: null hypothesis rejected at *, 10%; **, 5%; ***, 1% level of significance

[a] DF-GLS test statistic is -2.15** if lag length selected by SIC

There is a caveat to the above discussion however. The analysis in this paper tracked prices over what may be considered a short time period (12 years). Dixit and Pindyck (1994) stress that conclusions pertaining to the stochastic process of a series must be made with caution when using a short time series. Consequently, as time passes and more data become available, a similar analysis should be conducted to ensure the results are robust. Furthermore, past research has shown that results can differ with quarterly data.

We did have access to a longer quarterly time series of A grade prices going from 1973-2001 (this appears to be the same series used by Guthrie and Kumareswaran 2003) as well as a shorter quarterly series collected by the Ministry of Agriculture and Forestry (MAF).[12] We ran the same tests outlined above on this data and report the results in Table 5. The results coming from the shorter MAF series also support non-stationarity. However, unlike the monthly data, in a couple of instances this depended on whether or not a deterministic trend was included in the model. The results on the longer A grade series were inconclusive. Stationarity could not be rejected at the 10% level of significance with the KPSS test and non-stationarity could

[11] *Structural estimation of these models using methods such as two stage least squares are still consistent provided the series are co-integrated.*

[12] *The S3, L3 and the Pulp export series contained gaps, preventing us from conducting analysis.*

not be rejected at the 10% level of significance under the DF-GLS test. However, we did find some variance with the DF-GLS test depending on the lag-selection procedure. When lag was selected by the SIC, instead of the MAIC, the DF-GLS test rejected non-stationarity at the 5% level. This suggests that mean reversion may be a possibility with some grades over a longer time frame. These possibilities could be explored further in future research.

### References

Binkley, C.S., Washburn, C., Aronow, M.E., Fritzinger, T. (2001). Modeling future price uncertainty. *Hancock Timberland Investor*, first quarter 2001. (http://www.htrg.com/research_lib/current_n_archives.html).

Black, Fischer; Myron Scholes (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, 81: 637-654.

Brazee, R., and Mendelsohn, R. (1988). Timber harvesting with fluctuating prices. *Forest Science*, 34: 359-372.

Clarke, H.R. and Reed, W.J. (1989). The tree-cutting problem in a stochastic environment: The case of age-dependent growth. *Journal of Economic Dynamics and Control*, 13: 569-595.

Dickey, D.A., and Fuller, W.A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of American Statistics Association*, 74: 427-43.

Dixit, A., and Pindyck, R. (1994). Investment under uncertainty. Princeton University Press, Princeton, NJ.

Elliot, G., Rothenberg, T., and Stock, J.H. (1996). Efficient tests for an autoregressive unit root. *Econometrica*, 64: 813-836.

Fama, E.F. (1970). Efficient capital markets: a review of theory and empirical work. *Journal of Finance*, 25: 383-417.

Gong, P., Löfgren, K.G. 2007. *Market and welfare implications of the reservation price strategy for forest harvest decisions*. Journal of forest economics, 13: 217-243.

Gujarati, D.N. (1995). Basic econometrics, Third Edition. McGraw Hill, New York.

Guthrie, G.A., and Kumareswaran, D.K. (2003). Carbon subsidies and optimal forest management. Report prepared for the New Zealand institute for the study of competition and regulation Inc.

Haight, R.G., and Holmes, T.P. (1991). Stochastic price models and optimal tree cutting: results for loblolly pine. *Natural Resources Modelling*, 5: 423-443.

Hobijn, B., Franses, P.H., and Ooms, M. (1998). Generalizations of the KPSS test for stationarity. *Econometric Institute Report 9802/A*, Econometric Institute, Erasmus University Rotterdam. (http://www.eur.nl/few/ei/papers).

Insey, M. and Rollins, K. (2005). On solving the multirotational timber harvesting problem with stochastic prices: a linear complementarity formulation. *American Journal of Agricultural Economics*, 87(3): 735-755.

Kwiatkowski, D., Phillips, P.C.B, Schmidt, P., and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics*, 54: 159-178.

Lee, D., and Schmidt, P. (1996). On the power of the KPSS test of stationarity against fractionally-integrated alternatives. *Journal of Econometrics*, 73: 285-302.

Lo, A., and MacKinlay, A. (2001). A non-random walk down Wall street. Princeton University Press, Princeton, NJ.

Malkiel, B.G. (2004). A random walk down Wall street. W.W. Norton and Company Inc., New York.

McGough, B., Plantinga, A.J., and Provencher, B. (2004). The dynamic behaviour of efficient timber prices. *Land Economics*, 80: 95-108.

New Zealand Forest Owners Association. (2006). New Zealand forest industry: facts and figures 2005/06. (http://www.nzfoa.org.nz/file_libraries_resources/facts_figures)

Ng, S., and Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. *Econometrica*, 69: 1519-1554.

Phillips, P.C.B., and Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75: 335-346.

Plantinga, A.J. (1998). The optimal timber rotation: an option value approach. *Forest Science*, 44: 192-202.

Prestemon, J. (2003). Evaluation of U.S. southern pine stumpage market informational efficiency. *Canadian Journal of Forest Research*, 33: 561-572.

Reed, W.J. (1993). The decision to conserve or harvest old-growth forest. *Ecological Economics*, 8: 45-69.

Said, S.E., and Dickey, D.A. (1984). Testing for unit roots in autoregressive moving average models of unknown order. *Biometrika*, 71: 599-607.

Song, N., and Chang, S.J. (2007). Nonstationarity, autocorrelation, and collinearity in modelling forest products markets. Presentation to the western forest economists meeting. Wemme, Oregon. (http://www.masonbruce.com/wfe/2007Program/Song.pdf)

Stock, J.H., and Watson, M.W. (2003). Introduction to econometrics. Addison-Wesley, New York.

Thompson, T.A. (1992). Optimal forest rotation when stumpage prices follow a diffusion process. *Land Economics*, 68: 329-342.

Washburn, C., and Binkley, C.S. (1990). Informational efficiency of markets for stumpage. *American Journal of Agricultural Economics*. 72: 394-405.

Yin, R., and Newman, D.H. (1995). A note on the tree cutting problem in the stochastic envirionment. *Journal of Forest Economics*, 1:181-90.

Yin, R., and Newman, D.H. (1996). Are markets for stumpage informationally efficient? *Canadian Journal of Forest Research*, 26: 1032-1039.