REGIONAL LOG MARKET INTEGRATION IN NEW ZEALAND

Kurt Niquidet [1,*] and Bruce Manley[2]

[1]*Resource Economics and Policy Analysis Research Group, Department of Economics, University of Victoria, PO Box 1700, STN CSC, Victoria, British Columbia, V8W 2Y2, Canada*

[2]*School of Forestry, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand*

(Received for publication 13 March 2008; accepted in revised form 21 October 2008)

ABSTRACT

In this paper the integration of log prices across four regions in New Zealand was assessed. A series of monthly prices from January 1995 to December 2006 for five radiata pine (*Pinus radiata* D. Don) log grades in each of the regions was tested for co-integration using Johansen's method and Engle-Granger pair-wise tests. Prices for export grades displayed significant integration across regions and generally followed the law of one price. However, markets for domestic grades tended to be regionally segregated. These results are most likely due to the high costs of transporting logs between regions. Future modelling will need to incorporate such transportation costs in order to adequately characterise log markets in the country.

Keywords: log market; co-integration; law of one price

INTRODUCTION

The integration of forestry markets has been the focus of a significant volume of research over the past two decades. In general, the focal point of this work has been on testing for the law of one price (LOP) and for delineating common regions for the purposes of regional trade modelling. To conduct these tests, co-integration methods are typically used (Engle & Granger, 1987; Johansen, 1988).

Pioneering modelling studies in forestry were conducted by Uri and Boyd (1990), Buongiorno and Uusivuori (1992) and Jung and Doroodian (1994), who examined regional integration in pulp and paper and lumber markets in the United States (U.S.).

*Corresponding author: niquidet@uvic.ca

Each of these studies found support for significant integration between markets and the LOP, although Thorsen (1998) suggested that Jung and Doroodian (1994) misinterpreted their results. Nonetheless, further studies enhanced the econometrics and found overwhelming support for a nationally integrated market for softwood lumber in the U.S. (Yin & Baek, 2005).

However, studies on integration in upstream roundwood and stumpage markets have found mixed, and somewhat contrasting, results. Yin et al. (2002) and Nagubadi et al. (2001) found that stumpage markets in the U.S. South were not fully integrated. They suggested these findings could be attributed to the bulky low value nature of timber which makes transportation costs high. Indeed, Prestemon and Holmes (2000) and Bingham et al. (2003) showed that co-integration tends to decay with distance from a reference market. Similarly, in their analysis of the regional Finnish roundwood market, Toppinen and Toivonen (1998) found that only one price series out of four were integrated and Mutanen and Toppinen (2007) discovered that only one of six log assortments (spruce sawlogs) were integrated in the Russian-Finnish roundwood trade. Furthermore, Toppinen et al. (2005) found that roundwood markets between Finland, Estonia and Latvia displayed little integration.

Conversely, Stevens and Brooks (2003) found that log markets between Alaska, coastal British Columbia and the U.S. Pacific Northwest were integrated, perhaps owing to the lower transportation costs associated with water transport. Additionally, Riis (1996) and Thorsen (1998) found significant integration in Nordic timber markets.

To date, little work has been done on the regional integration of the New Zealand log market. Bloomberg et al. (2002) studied the regional variation in New Zealand log prices between the years 1997 and 2000, finding that, even after controlling for log quality, regional differences in prices were still significant. However, economic theory suggests that price differences should not hold in the long run due to arbitrage. Firstly, we raise the question: Do these results hold over a longer time frame? Secondly, when examining prices over time, it is necessary to examine and account for the time series properties of the data. This study fills this gap by investigating the integration of log prices across four regions in New Zealand over a 12 year period from January 1995 to December 2006 by the use of standard co-integration methods. We feel such a study is necessary to improve the understanding of the dynamics of the log market in New Zealand which can then be incorporated into spatial partial equilibrium models of the forest products trade (Buongiorno et al., 2003; Turner et al., 2007). In addition, our study can potentially provide some preliminary guidance about market definition for purposes such as data aggregation and competition policy.

MATERIALS AND METHODS

Co-integration model structure

Many economic time series are non-stationary, containing a unit root. This creates problems with spurious regression and forecasting (Granger & Newbold, 1974). Although an individual price series (x_1) may be I(1), exhibiting a stochastic trend, another price series (x_2) may exhibit the same stochastic trend such that a linear combination of the two series is a stationary I(0) series. If this is the case, the two series are said to be co-integrated and have a long run relationship between one another. This relationship can be represented in a co-integrating equation as follows:

$$x_{1_t} = c + \beta x_{2_t} + v_t \quad [1]$$

Where c is a constant term, β is the co-integrating parameter reflecting the long run relationship between the series, and v is a white noise disturbance term. The co-integrating equation is often used to examine the LOP; under the strong version $c = 0$ and $\beta=1$, but this is often relaxed and a weak version is applied allowing $c \neq 0$ reflecting transport and transfer costs between regions.

To test for co-integration Engle and Granger (1987) proposed that one would first need to estimate Equation [1] by the Ordinary Least Squares (OLS) method and then analyse the residuals $\bar{v}_t$ from this regression. If the series are co-integrated, then OLS is a consistent estimator of the co-integrating parameter, and $\bar{v}_t$ should not contain a unit root, that is it should be stationary. A Dickey Fuller (DF) or Augmented Dickey Fuller (ADF) test on the residual series is, therefore a test for co-integration; if a unit root is rejected then one can conclude the two series are co-integrated. Engle and Granger (1987) modified the DF critical values to reflect the fact that $\bar{v}_t$ had been estimated. These critical values were later improved by Davidson and MacKinnon (1993) and we employ these values in our testing.

The problem with the Engle-Granger approach is its inability to incorporate more than one co-integrating relationship. Also, prices can simultaneously influence one another, leading to an endogeneity problem in the Engle-Granger framework (Stock & Watson, 2003). Johansen (1988) solved this by extending the co-integration analysis into a multivariate format. Prices were modelled by the following vector autoregressive model (VAR) of dimension k:

$$\mathbf{x}_t = \mathbf{A}_1 \mathbf{x}_{t-1} + \ldots + \mathbf{A}_p \mathbf{x}_{t-p} + \boldsymbol{\mu} + \Phi \mathbf{d}_t + \varepsilon_t \quad [2]$$

where t and p represent time period and lag length respectively, $\mathbf{x}_t$ is a vector of endogenous prices (k x 1), $\mathbf{A}_i$ is a (k x k) matrix of coefficients to be estimated, $\boldsymbol{\mu}$ is a (k x 1) vector of constant terms, $\mathbf{d}_t$ is a (z x 1) vector of deterministic variables, such as trends, seasonal dummy variables etc., and ε_t is a vector (k x 1) of error terms which are assumed to be normally, independently and identically distributed. To test for co-integration, the model was transformed into the following Vector Error Correction Model (VECM):

$$\Delta \mathbf{x}_t = \Gamma_1 \Delta \mathbf{x}_{x-1} + ,\ldots, + \Gamma_{k-1} \Delta \mathbf{x}_{t-p+1} + \Pi \mathbf{x}_{t-p} + \boldsymbol{\mu} + \varepsilon_t, t = 1,\ldots, T \quad [3]$$

where

$$\Gamma_i = -(\mathbf{A}_2 +, \ldots, + \mathbf{A}_i) \text{ with } i = 1,\ldots, p\text{-}1 \text{ and } \Pi = -(\mathrm{I} - \mathbf{A}_1 -, \ldots, -\mathbf{A}_p).$$

The focus of Johansen's method is on the matrix Π and its rank. For the rank of Π also represents the number of co-integrated relationships in the system (r). When r is equal to zero, there are no co-integrating relations and the model is just a VAR in differenced data. At the other extreme, if r = k then the original price series is most likely already stationary. The case of interest however is when $1 \leq r \leq k\text{-}1$; then there exists co-integration among some of the prices. In the special case where all of the regional markets are fully co-integrated, then $r = k\text{-}1$.

Johansen developed two tests for the rank of the matrix Π; the most popular being the trace test and the other being the maximum eigenvalue test. Both tests are likelihood ratio based and have the same null hypothesis; however they differ in their alternative hypothesis. The trace test stipulates H_0: rank(Π) = r_0 vs. H_1: rank(Π) = >r_0 whereas the maximum eigenvalue test is H_0: rank(Π) = r_0 vs. H_1: rank(Π) = r_0 + 1. In either instance, one begins by testing whether r = 0 and proceeds iteratively by increasing r_0 if the null hypothesis is rejected. Based on several simulations Lütkepohl et al. (2001) suggested the trace test is generally preferable, therefore, we use it in this paper.

Gonzalo (1994) also showed that the correct order selection (p) in the underlying VAR model is critical in the proper determination of co-integration vectors and rank. Several selection statistics are available including sequential likelihood ratio tests and information criteria (IC) such as Akaike (AIC), Hannan and Quinn (HQIC), and Schwarz (SIC). Ivanov and Kilian (2005) reviewed these selection criteria in VAR models and concluded that likelihood ratio tests tend to underperform the information criteria. However, the performance of each information criteria relative to one another depends on several factors, most notably the frequency and size of the data. For monthly data, as sample size increases the AIC tends to dominate both the HQIC and SIC. However, in smaller samples (≤240 observations) there does not seem to be much difference between the criteria. As we will describe later, our data falls into this small sample category. Therefore, we relied on the AIC, but performed sensitivity testing when there were conflicts between it and the SIC.

Another important factor in Johansen's testing framework was the inclusion of deterministic variables in the underlying VAR model. Different deterministic variables can significantly alter the critical values in the trace test and, therefore, can affect conclusions pertaining to the number of co-integrating relations (Osterwald-Lenum, 1992). Generally, five possible cases are considered, these cases are:

1. no deterministic components;
2. constant in co-integrating equation but not in VAR;
3. constant in VAR;
4. constant in VAR, trend in co-integrating equation; and
5. constant in VAR, trend in VAR.

The proper case depends on the characteristics of the levels data $\mathbf{x}_t$. Case 1 is rare and is only appropriate when the initial data begins at zero (Juselius, 2006). Similarly, case 5 is also rare and is restricted to series that display quadratic trends. Case 2 is common for data that is un-trended in levels and cases 3 and 4 are for linearly trended data.

Law of one price

As mentioned earlier, if the series are co-integrated one can test further restrictions pertaining to the LOP by examining the co-integration equation. The OLS method is a super consistent estimator of the parameters in Equation [1] if the two series are co-integrated (Stock, 1987). One would naturally think that it would then be straightforward to test for the various versions of the LOP by standard *t* or *F* tests after the OLS regression is performed. Unfortunately, this is not always the case as these statistics do not always have the usual distributions, due to simultaneity issues (Stewart, 2005, p. 822). A more robust method for testing for the LOP, therefore, lies in the VECM system analysis.

The matrix Π can be broken down into a matrix of loading vectors, α and a matrix of co-integrating vectors, β (i.e. $\Pi = \alpha\beta'$). The focus of testing is on the matrix β'; the LOP is imposed by restricting the matrix to the following (Nyrud, 2002):

$$\beta' = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ -1 & 0 & \cdots & 0 \\ 0 & -1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & -1 \end{bmatrix} \qquad [4]$$

A likelihood ratio test distributed χ^2 with *r* degrees of freedom is used to test the restriction.

Data

We utilised the same data reported in Niquidet and Manley (2007), a more complete description of the data can be found there. This data was retrieved from the reporting agency Agri-fax (http://www.agri-fax.co.nz/forestry.cfm) and contains monthly prices from January 1995 to December 2006 for five grades of radiata pine logs across four New Zealand regions.[1] The grades are specified in Table 1 as described by Agri-fax and the regions are: (1) Northern North Island (NNI); (2) Southern North Island (SNI); (3) Northern South Island (NSI); and (4) Southern South Island (SSI). Prices are NZ $/t delivered to mill (domestic grades) or wharf (export grades). Graphs of these price series can be found in the Appendix.

TABLE 1: New Zealand log grade specifications[a]

Specification	Log Grade				
	P1	P2	KS	S1/S2	Pulp
Pruned	yes	yes	no	no	no
Minimum small end diameter (cm)	40	35	20	40/30	10
Maximum branch size (cm)	n/a	n/a	10	6	n/a
Minimum Length (m)	4	4	4	4.95 to 6.1	fixed/random
Destination market	Domestic	Domestic	Export	Domestic	Domestic/Export

[a] Source: Adapted from Agri-fax
n/a - not applicable

Unit root (Elliot et al., 1996) and stationary tests (Kwiatkowski et al., 1992) conducted by Niquidet and Manley (2007) suggested that all of the prices are non-stationary I(1) processes, with the exception of pulp log prices on the North Island.[2] Seeing that the Johansen and Engle-Granger procedures rely on prices being I(1), these North Island pulp log prices were excluded from our co-integration analysis.

[1] The price series for both pulp logs in the SSI and P1 in the SNI were shorter due to missing observations. Consequently, co-integration analysis spans from June 1997 to December 2006 for pulp logs and from January 1996 to December 2006 for P1 logs.

[2] Like Niquidet and Manley (2007) and the majority of other price integration studies, we used prices transformed by the natural log for analysis.

RESULTS

In spite of the issues with the Engle-Granger method, we conducted pair wise co-integration tests across region and grade. Like Yin et al. (2002) we did this because of the simplicity and flexibility associated with this approach and for the sake of comparison with the more complex, yet robust, Johansen method. Also, Kennedy (2003) suggested that when there is only one co-integrating relationship, the Engle-Granger method is preferable to the Johansen method because it is less sensitive to the inclusion of deterministic components. The results from these pair wise tests can be found in Table 2. The tests were augmented with lags, selected by the SIC and included a constant (including a trend term was not significant nor did it alter our conclusions).

TABLE 2 : Engle Granger co-integration tests

Log Grade	Market	Possible Co-integration Region		
		NSI	SSI	NNI
P1	SSI	-2.02		
	NNI	-3.22	-2.17	
	SNI	-3.83*	-2.07	-3.34*
P2	SSI	-1.59		
	NNI	-2.92	-3.24	
	SNI	-2.85	-3.50*	-3.40*
KS	SSI	-4.61**		
	NNI	-3.28	-4.93**	
	SNI	-4.49**	-4.40**	-4.30**
S1/S2	SSI	-2.57		
	NNI	-2.67	-2.96	
	SNI	-2.71	-2.88	-2.44
Pulp	SSI	-3.44*		

* Unit root rejected at 5%;
** Unit root rejected at1% using Davidson and MacKinnon (1993) critical values

The results, in general, do not support full co-integration of prices across regional markets. The exception to this was the export grade KS logs where the results essentially support full integration. There also appeared to be co-integration on the North Island for pruned logs and on the South Island for pulp logs. Lastly, a co-integration relationship existed between NSI and SNI for the P1 grade and between SSI and SNI for the P2 grade.

For these co-integrated series, we also report the OLS estimate of Equation [1] and the results of the LOP t tests.[3] These results are reported in Table 3.

Table 3 – Law of one price testing using co-integrated price pairs

Log Grade	Dependent Variable	Explanatory Variables		R^2
	Region	Region	Constant	
P1	NSI	SNI 0.493†	2.502*	0.785
	NNI	SNI 1.192†	-0.994*	0.975
P2	SSI	SNI 0.831†	0.610*	0.708
	NNI	SNI 1.239†	-1.224*	0.973
KS	NSI	SSI 0.984	0.074	0.943
	NSI	SNI 1.012	-0.076	0.882
	SSI	NNI 1.020	-0.128	0.897
	SSI	SNI 1.001	-0.040	0.888
	NNI	SNI 0.977	0.107*	0.990
Pulp	NSI	SSI 0.444†	2.094*	0.192
	NNI	SNI 0.765†	0.920*	0.719

* Significantly different than zero at 5% level;
† Significantly different than one at 5% level

[3] Note that Table 3 also reports LOP tests for pulp prices on the North Island as these series were stationary (Niquidet & Manley, 2007).

The t tests rejected the LOP for three grades, P1, P2 and Pulp logs. However, the LOP was supported for the export price series KS (although only the weak LOP existed between the NNI and SNI). However, these t tests should be taken in context as endogeneity problems discussed earlier could affect their properties, particularly for KS logs where there is more than one co-integrating relationship. We, therefore, turned next to the Johansen system method.

In general, the levels data were trending slightly downward, but often not significantly (Niquidet & Manley, 2007). Consequently, we thought case two was most appropriate (constant in the co-integrating equation but not the VAR), and initially ran the Johansen's test based on this. The results of the trace tests associated with this formulation can be found in Table 4.

TABLE 4: Johansen's trace test results, lag selection by Akaike Information Criterion

Log Grade	Lag	Null hypothesis	Trace statistic	5% critical value[a] (case 2)
P1	2	$r = 0$	43.69	53.12
		$r \leq 1$	23.58	34.91
		$r \leq 2$	11.15	19.96
		$r \leq 3$	4.51	9.24
P2	3	$r = 0$	57.80*	53.12
		$r \leq 1$	30.29	34.91
		$r \leq 2$	13.70	19.96
		$r \leq 3$	2.88	9.24
KS	2	$r = 0$	78.64*	53.12
		$r \leq 1$	50.93*	34.91
		$r \leq 2$	26.12*	19.96
		$r \leq 3$	6.46	9.24
S1/S2	2	$r = 0$	45.04	53.12
		$r \leq 1$	26.91	34.91
		$r \leq 2$	15.43	19.96
		$r \leq 3$	5.17	9.24
Pulp	1	$r = 0$	31.76*	19.96
		$r \leq 1$	5.14	9.24

* Reject null hypothesis at 5% significance level
[a] Critical values from Osterwald-Lenum (1992)

Only the export grade KS was fully integrated across all regions, as the trace test suggested that there were three co-integrating relationships among the four price series. Pulp log prices between the two regions on the South Island also appeared to be integrated and there existed a single co-integrating relationship among the P2 log prices. However, for all the other domestic log grades, markets were regionally segregated. These conclusions proved not to be very sensitive to the inclusion of deterministic terms, as the altered tests associated with linearly trended data (cases three and four) did not affect conclusions pertaining to the rank of Π.

In contrast, results were sensitive to order selection in the VAR. The results in Table 4 are based on lag selected by the AIC. With the exception of pulp logs, the SIC called for a different, shorter, lag structure. Table 5 presents the trace test results based on the order selected by the SIC. Under this model, more co-integrating relations were found. Perhaps most notably, the trace test now pointed to a co-integrating relationship among the prices for the domestic log grade, P1. This result is also more consistent with the pair wise Engle-Granger tests reported earlier. However, a national integrated domestic log market continues to be broadly rejected.

TABLE 5: Johansen's trace test results, lag selection by Schwarz Information Criterion

Log Grade	Lag	Null hypothesis	Trace statistic	5% critical value[a] (case 2)
P1	1	$r = 0$	55.13*	53.12
		$r \leq 1$	34.08	34.91
		$r \leq 2$	15.49	19.96
		$r \leq 3$	3.79	9.24
P2	1	$r = 0$	57.16*	53.12
		$r \leq 1$	28.77	34.91
		$r \leq 2$	11.15	19.96
		$r \leq 3$	3.26	9.24
KS	1	$r = 0$	81.47*	53.12
		$r \leq 1$	46.02*	34.91
		$r \leq 2$	18.52	19.96
		$r \leq 3$	4.31	9.24
S1/S2	1	$r = 0$	45.04	53.12
		$r \leq 1$	26.91	34.91
		$r \leq 2$	15.43	19.96
		$r \leq 3$	5.17	9.24

* Reject null hypothesis at 5% significance level (case 2)
[a] Critical values from Osterwald-Lenum (1992)

We then focused on the KS grade as the trace test suggests that it is the only series that is fully integrated nationally (three co-integrating equations) and tested for the more restrictive LOP across regions. Table 6 reports the normalized co-integrated β matrix and their weights α from the unrestricted co-integration model of KS prices (Equation [3]).

TABLE 6: Normalized eigenvectors, β, and their weights, α, obtained from co-integration Equation [3].

	Eigenvectors			Weights		
Region	β1	β2	β3	α1	α2	α3
NSI	1	0.000	0.000	0.014	-0.157	0.617
SSI	0.000	1	0.000	0.270	-0.380	0.387
NNI	0.000	0.000	1	0.147	-0.042	0.196
SNI	-1.139	-1.095	-1.031	0.137	-0.024	0.465

The matrix was then restricted according to Equation [4] to reflect the LOP hypothesis. We failed to reject this hypothesis as the likelihood ratio statistic was $\chi^2(3) = 2.332$ with a P-value of 0.508

DISCUSSION

Domestic log grades in New Zealand do not appear to be co-integrated across regions to much degree; however export grades do display significant integration. Like Yin et al. (2002) and Bingham et al. (2003), we suspect that transaction costs are the main reason for this lack of integration in the domestic market, the key one being transportation. A failure to integrate across regions may also be attributed to regional differences in wood quality, particularly with regard to intrinsic properties such as stiffness or wood density. Such a phenomenon has received little attention to date and is something that could be explored further. Finally, there may be an issue with the aggregation of prices within a region, as the regions studied in this paper are large and include mills at different localities.

Also, one must be aware of the limitations associated with co-integration analysis. Barrett (1996) showed that co-integration is not a necessary or sufficient condition for market integration. He emphasised the need for analysis to move beyond price data, and incorporate trade flows and transaction costs. Similarly, McNew and Fackler (1997) advised caution in using co-integration for analysing spatial price behaviour. They showed that if the underlying forces affecting local supply and demand in different regions are not co-integrated, neither will prices across regions, even with arbitrage. This kicked off a host of alternative models in agriculture economics (Barrett &Li, 2002; Goodwin & Piggott, 2001; Sephton, 2003; Balcolmbe et al., 2007) which to date have not yet spilled over into the forest economics literature.[4] Unfortunately, lack of readily available transportation cost and trade flow data currently prevents a richer analysis such as Barrett and Li (2002). Furthermore, these models also have their drawbacks, as they use seemingly arbitrary distributional assumptions (Barrett, 2005).

[4] A possible exception to this has been work done by Zhou and Buongiorno (2006). While they did not explicitly incorporate transaction costs between regions, their model allowed for spatial dependence between regions. Furthermore, Bingham et al. (2003) showed that transfer costs between regions are negatively related to the probability that log market prices are co-integrated.

Future research may also proceed by simultaneously estimating both integration and transaction costs via threshold integration. However, the linear co-integration tests employed in this paper have been shown to be relatively robust even when nonlinear threshold co-integration is present, though they tend to have low power when there are multiple thresholds (Balke & Fomby, 1997; Enders & Granger, 1998). Indeed, tests for threshold integration (Tsay, 1989; Hansen, 1999; Hansen & Seo, 2002) are recommended only as a second step once co-integration has been found in the linear case (Balke & Fomby, 1997; Lo & Zivot, 2001). Moreover, these threshold models assume that transaction costs are constant, an assumption that seems unreasonable for the time frame that our price series covers. To deal with such a situation, Goodwin and Piggott (2001) concluded that direct observations on actual transaction costs are needed. Some research on various types of time varying threshold models could also be explored (Park et al., 2007).

In spite of the above issues with co-integration analysis, preliminarily, our results do suggest that log market definition in New Zealand is usually at a finer scale than a national level, at least for domestic grades. Incorporating this regional segregation into timber market models, therefore, could also be the subject of future research. Consequently, these results imply that care should be taken when using log price data that aggregate across regions, such as that collected by the Ministry of Agriculture and Forestry (MAF) (2008). Such data can introduce spatial aggregation bias into econometric models of the domestic log market. MAF, therefore, may think about disaggregating their price series for future reporting. Also, to uncover greater understanding about the dynamics of the log market in New Zealand, collection of data on regional trade flows and transportation costs would be helpful.

The segregated nature of the domestic market also has implications for competition policy. According to Forni (2004), our research indicates that regional delineation is necessary for market definition and the measurement of market concentration. However, Hosken and Taylor (2004) pointed out that quantity data are needed to get a more accurate depiction of geographical markets. Furthermore, any competition policy must also carefully define product markets. In this context, the substitutability between domestic and export grades in a region should be considered. To do so, quantity data will also be of benefit (Hosken & Taylor, 2004).

CONCLUSION

In this paper we assessed the integration of regional log markets in New Zealand. Co-integration methods suggest that the domestic log market is segregated but markets for export logs are more or less integrated. Explaining the lack of integration in the domestic market might be the subject of subsequent research. This will need to incorporate factors such as transportation costs (both within and between regions), regional supply and demand dynamics, and localised wood quality factors.

REFERENCES

Balcolmbe, K., Bailey, A., & Brooks, J. (2007). Threshold effects in price transmission: the case of Brazilian wheat, maize, and soya prices. *American Journal of Agricultural Economics, 89,* 308-323.

Balke, N. S., & Fomby, T. B. (1997). Threshold cointegration. *International Economic Review, 38,* 627-645.

Barrett, C. B. (1996). Market analysis methods: Are our enriched toolkits well suited to enlivened markets? *American Journal of Agricultural Economics, 78,* 825-29.

Barrett, C. B. (2005). Spatial Market Integration. In L. W. Blume & S. N. Durlauf (Eds). *The New Palgrave Dictionary of Economics*. London: Palgrave Macmillan.

Barrett, C. B., & Li, J. R. (2002). Distinguishing between equilibrium and integration in Spatial Price Analysis. *American Journal of Agricultural Economics, 84*, 292-307.

Bingham, M. F., Prestemon, J. P., Macnair, D. J., & Abt, R. C. (2003). Market structure in U.S. southern pine roundwood. *Journal of Forest Economics, 9,* 97-117.

Bloomberg, M., Bigsby, H., & Sedcole, R. (2002). Regional variation in radiata pine sawlog prices in New Zealand. *New Zealand Journal of Forestry, 45,* 25-27.

Buongiorno, J., & Uusivuori, J. (1992). The law of one price in the trade of forest products: co-integration tests for U.S. exports of pulp and paper. *Forest Science, 38,* 539-553.

Buongiorno, J., Zhu, S., Zhang, D., Turner, J., & Tomberlin, D. (2003). *The global forest products model.* San Diego, CA: Elsevier Science.

Davidson, R., & Mackinnon, J. G. (1993). *Estimation and inference in econometrics*. Oxford: Oxford University Press.

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

Enders, W., & Granger, C. W. J. (1998). Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates. *Journal of Business and Economic Statistics, 16,* 304-311.

Engle, R. F., & Granger, C. W. J. (1987). Dynamic model specification with equilibrium constraints: Co-integration and error-correction. *Econometrica, 55,* 251-76.

Forni, M. (2004). Using stationarity tests in antitrust market definition. *American Law and Economics Review, 6,* 441-464.

Gonzalo, J. (1994). Five alternative methods of estimating long-run equilibrium relationships. *Journal of Econometrics, 60,* 203-233.

Granger, C. W. J., & Newbold, P. (1974). Spurious regressions in econometrics. *Journal of Econometrics, 2,* 111-120.

Goodwin, B. K., & Piggott, N. (2001). Spatial market integration in the presence of threshold effects. *American Journal of Agricultural Economics, 83,* 302-317.

Hansen, B. E. (1999). Testing linearity. *Journal of Economic Surveys, 13,* 551-576.

Hanson, B. E., & Seo, B. (2002). Testing for two-regime threshold cointegration in vector error-correction models. *Journal of Econometrics, 110*, 293-318.

Hosken, D., & Taylor, C. T. (2004). Discussion of "Using stationarity tests in antitrust market definition". *American Law and Economics, 6,* 465-475.

Ivanov, V., & Kilian, L. (2005). A practitioner's guide to lag order selection for VAR impulse response analysis. *Studies in Nonlinear Dynamics and Econometrics, 9*(1), article 2. Retrieved online http://www.bepress.com/snde/vol9/iss1/art2/.

Johansen, S. (1988). Statistical analysis of cointegrating vectors. *Journal of Economic Dynamic Control, 12,* 231-254.

Jung, C., & Doroodian, K. (1994). The law of one price for U.S. softwood lumber: a multivariate cointegration test. *Forest Science, 40,* 595-600.

Juselius, K. (2006). *The cointegrated VAR model: methodology and applications.* Oxford: Oxford University Press.

Kennedy, P. (2003). *A guide to econometrics.* Cambridge, MA: MIT Press.

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & 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.

Lo, M. C., & Zivot, E. (2001). Threshold cointegration and nonlinear adjustment to the law of one price. *Macroeconomic Dynamics, 5,* 533-576.

Lütkepohl, H., Saikkonen, P., & Trenkler, C. (2001). Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. *The Econometrics Journal, 4,* 287-310.

Ministry of Agriculture and Forestry. (2008). Indicative Radiata Pine Log Prices. Retrieved online http://www.maf.govt.nz/forestry/statistics/logprices/

McNew, K., & Fackler, P. (1997). Testing market equilibrium: is cointegration informative? *Journal of Agricultural and Resource Economics, 22,* 191-207.

Mutanen, A., & Toppinen, A. (2007). Price dynamics in the Russian-Finnish roundwood trade. *Scandinavian Journal of Forest Research, 22,* 71-80.

Nagubadi, V., Munn, I. A., & Tahai, A. (2001). Integration of hardwood stumpage markets in the south central United States. *Journal of Forest Economics, 7,* 69-75.

Niquidet, K., & Manley, B. (2007). Price dynamics in the New Zealand log market. *New Zealand Journal of Forestry, 52,* 4-9.

Nyrud, A. Q. (2002). Integration in the Norwegian pulpwood market: domestic prices versus external trade. *Journal of Forest Economics, 8,* 213-225.

Osterwald-Lenum, M. (1992). A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics: four cases. *Oxford Bulletin of Economics and Statistics, 54*, 461-72.

Park, H., Mjelde, J. W., & Bessler, D. A. (2007). Time-varying threshold cointegration and the law of one price. *Applied Econometrics, 39,* 1091-1105.

Prestemon, J. P., & Holmes, T. P. (2000). Timber price dynamics following a natural catastrophe. *American Journal of Agricultural Economics, 82,* 145-160.

Riis, J. (1996). Forecasting Danish timber prices with an error correction model. *Journal of Forest Economics, 2,* 157-271.

Sephton, P. E. (2003).: Spatial market arbitrage and threshold cointegration. *American Journal of Agricultural Economics, 85,* 1041-46.

Stevens, J. A., & Brooks, D. J. (2003). Alaska softwood market arbitrage. *Research Paper PNW-RP-556.* Oregon: USDA Forest Service Pacific Northwest Research Station.

Stewart, K. G. (2005). *Introduction to applied econometrics.* Belmont, CA: Brooks/Cole.

Stock, J. H. (1987). Asymptotic properties of least-squares estimators of co-integrating vectors. *Econometrica, 55,* 1035-1056.

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

Thorsen, B. J. (1998). Spatial integration in the Nordic timber market: Long-run equilibrium and short-run dynamics. *Scandinavian Journal of Forest Research, 13,* 488-498.

Toppinen, A., & Toivonen, R. (1998). Roundwood market integration in Finland: A multivariate co-integration analysis. *Journal of Forest Economics. 4,* 241-262.

Toppinen, A., Viitanen, J., Leskinen, P., & Toivonen, R. (2005). Dynamics of roundwood prices in Estonia, Finland and Lithuania. *Baltic Forestry, 11,* 88-96.

Turner, J., Katz, A., & Buongiorno, J. (2007). Implications for the New Zealand wood products sector of trade distortions due to illegal logging. Report prepared for the Ministry of Agriculture and Forestry. Retrieved online http://www.maf.govt.nz/forestry/illegal-logging/trade-distortion-implications/index.htm

Tsay, R. (1989). Testing and modelling threshold autoregressive processes. *Journal of the American Statistical Association, 93,* 1188-1202.

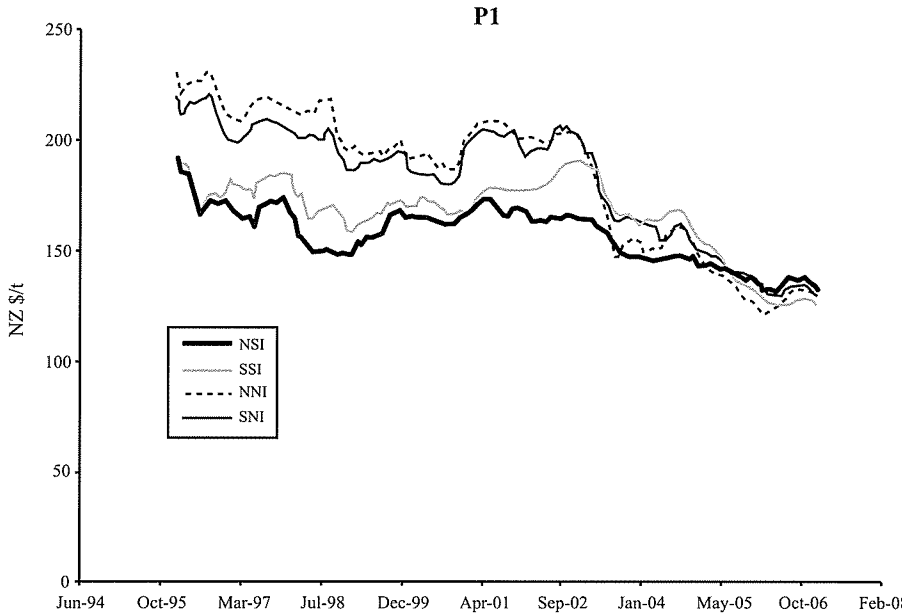
Uri, N., & Boyd, R. (1990). Considerations on modelling the market for softwood lumber in the United States. *Forest Science, 36,* 680-692.

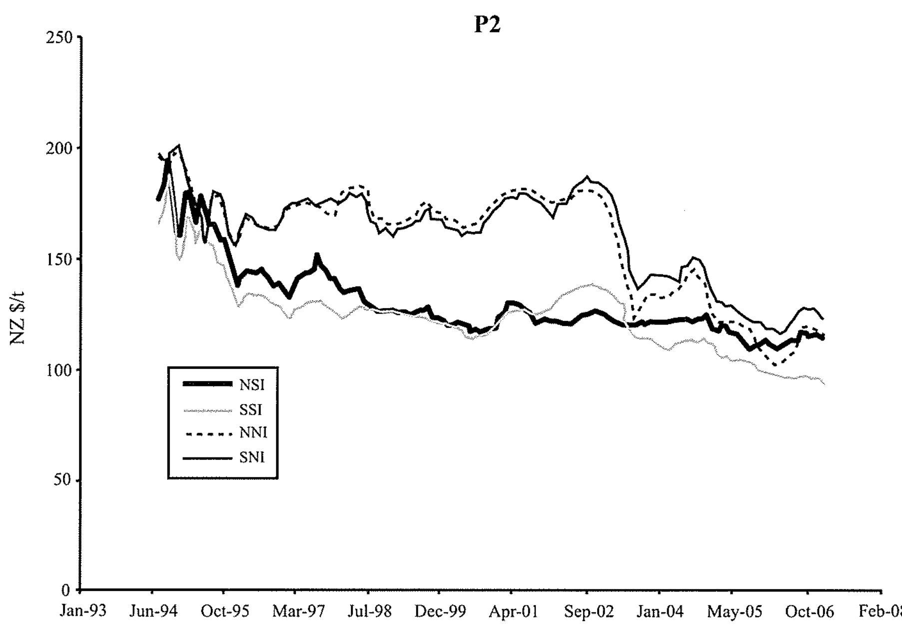
Yin, R., Newman, D. H., & Siry, J. (2002). Testing for market integration among southern pine regions. *Journal of Forest Economics, 8,* 151-166.

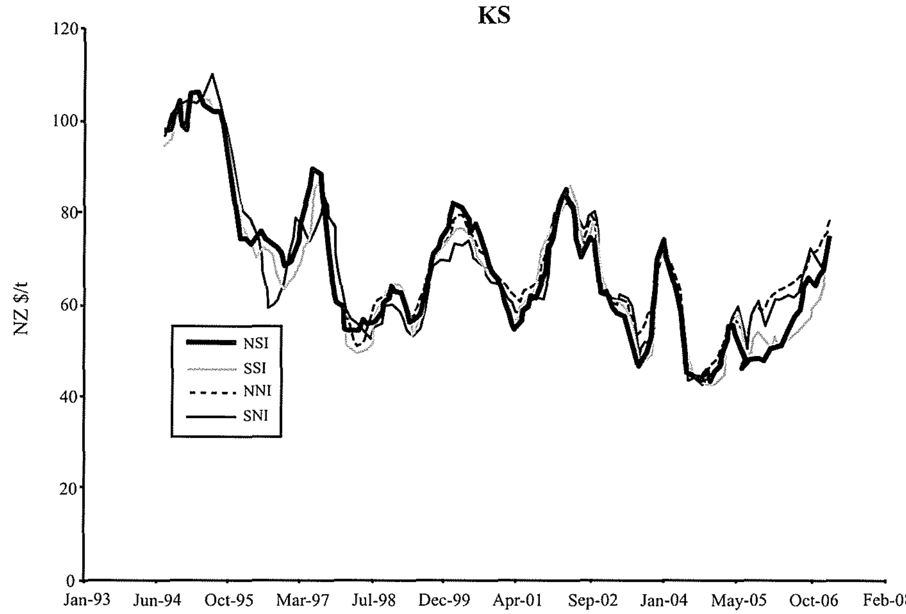
Yin, R., & Baek, J. (2005). Is there a single national lumber market in the United States? *Forest Science, 51,* 155-164.

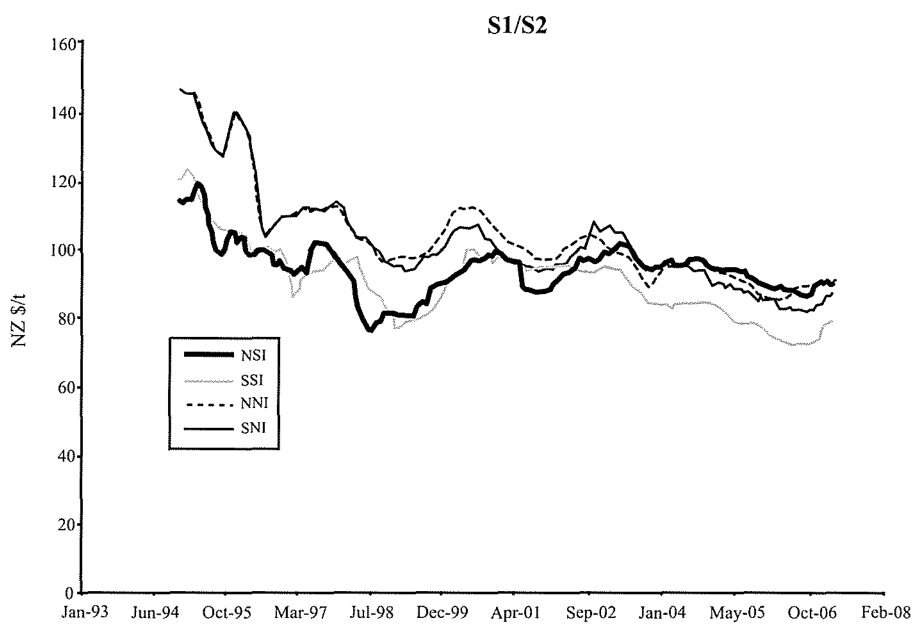
Zhou, M., & Buongiorno, J. (2006). Space-time modelling of timber prices. *Journal of Agricultural and Resource Economics, 31,* 40-56.

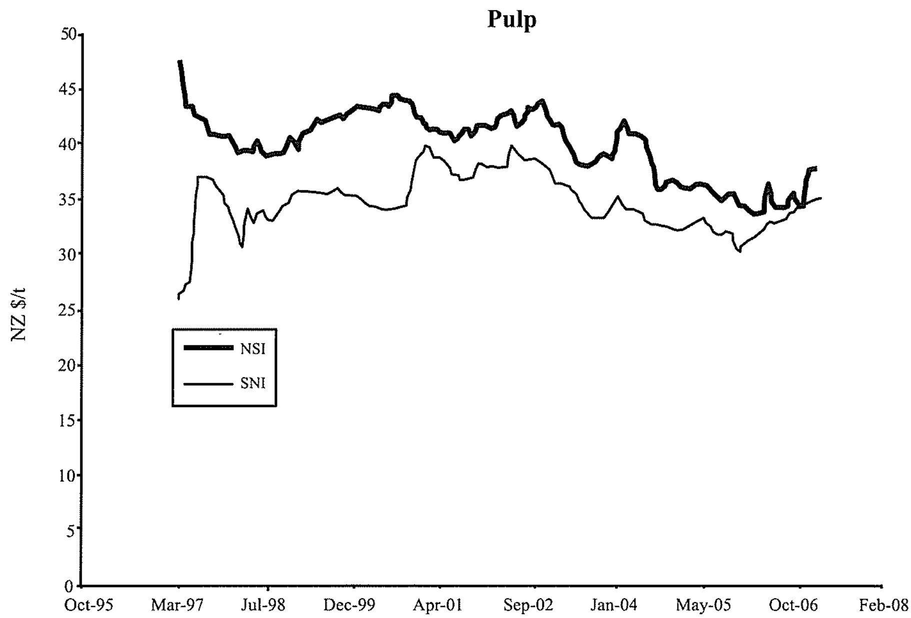
Appendix: Real log prices (2006 NZ $/t) for P1, P2, KS, S1/S2 and Pulp log grades for Northern North Island (NNI), Southern North Island (SNI), Northern South Island (NSI) and Southern South Island (SSI).






KS
NZ $/t
0
20
40
60
80
100
120
Jan-93
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
NSI
SSI
NNI
SNI


S1/S2
NZ $/t
0
20
40
60
80
100
120
140
160
Jan-93
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
NSI
SSI
NNI
SNI



Pulp
NZ $/t
50
45
40
35
30
25
20
15
10
5
0
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
NSI
SNI