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REGIONAL LOG MARKET INTEGRATION IN NEW ZEALAND

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REGIONAL LOG MARKET INTEGRATION IN NEW ZEALAND

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ABSTRACT

In this paper the integration of log prices across four regions in New Zealand was assessed. A time series of prices for six radiata pine (*Pinus radiata* D. Don) log grades in each of the regions were tested for co-integration using Johansen's method and Engle-Granger pair wise tests. Prices for export grades display significant integration across regions and generally follow the law of one price. However, markets for domestic grades tend 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 and Granger 1987, Johansen 1988).

Pioneering studies in forestry were conducted by Uri and Boyd (1990), Buongiorno and Uusivuori (1992) and Jung and Doroodian (1994), examining regional integration in pulp and paper and lumber markets in the United States (U.S.). Each of these studies found support for significant integration between markets and the LOP, although Thorsen (1998) suggests 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 and 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) find that stumpage markets in the U.S. South are not fully integrated. They suggest these findings can be attributed to the bulky low value nature of timber which makes transportation costs high. Similarly, in their analysis of the regional Finnish roundwood market, Toppinen and Toivonen (1998) find that only one price series out of four were integrated and Mutanen and Toppinen (2007) discover that only one of six log assortments (spruce sawlogs) are integrated in the Russian-Finnish roundwood trade. Furthermore, Toppinen et al. (2005) find that roundwood markets between Finland, Estonia and Latvia display little integration.

Conversely, Stevens and Brooks (2003) find that log markets between Alaska, coastal British Columbia and the U.S. Pacific Northwest are integrated, perhaps owing to the lower transportation costs associated with water transport. Additionally, Riis (1996), and Thorsen (1998) find 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 are still significant. However, economic theory suggests that price differences should not hold in the long run due to arbitrage. 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 by the use of 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). They can also provide some preliminary guidance about market definition for purposes such as data aggregation and competition policy.

The rest of this article is structured as follows. The next section provides an overview of testing methodology for co-integration and the LOP. This is followed by an outline of the data to be tested, including a description of the New Zealand regions and log grades we study. Ensuing this is our results and a brief discussion. The last section concludes.

METHODOLOGY

Co-integration

Many economic time series are non-stationary, containing a unit root. This creates problems with spurious regression and forecasting (Granger and 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:

$$x_{1t} = c + \beta x_{2t} + v_t \qquad (1)$$

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 β=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 Ordinary Least Squares (OLS) and then analyse the residuals $\hat{v}_t$ from this regression. If the series are co-integrated, then OLS is a consistent estimator of the co-integrating parameter, and $\hat{v}_t$ 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) modify the DF critical values to reflect the fact that v_t has 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 and Watson 2003). Johansen (1988) solved this by extending the co-integration analysis into a multivariate format. Prices are modelled by the following vector autoregressive model (VAR) of dimension *k*.

$$\mathbf{x}_t = \mathbf{A}_1\mathbf{x}_{t-1} + \ldots + \mathbf{A}_p\mathbf{x}_{t-p} + \boldsymbol{\mu} + \Phi\mathbf{d}_t + \boldsymbol{\varepsilon}_t \qquad (2)$$

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 $\boldsymbol{\varepsilon}_t$ 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 is transformed into the following Vector Error Correction Model (VECM):

$$\Delta \mathbf{x}_t = \mathbf{\Gamma}_1 \Delta \mathbf{x}_{x-1} +,...,+ \mathbf{\Gamma}_{k-1} \Delta \mathbf{x}_{t-p+1} + \mathbf{\Pi x}_{t-p} + \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t, t = 1,...,T \qquad (3)$$

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

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) suggests the trace test is generally preferable, we therefore use it in this paper.

Gonzalo (1994) also shows 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 such as Akaike (AIC), Hannan and Quinn (HQIC) and Schwarz (SIC). Ivanov and Kilian (2005) review these selection criteria in VAR models and conclude 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 rely on the AIC, but perform sensitivity testing when there are conflicts between it and the SIC.

Another important factor in Johansen's testing framework is 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 conclusion 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
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 (Juselisus 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. OLS 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 due to simultaneity issues these statistics do not always have the usual distributions (Stewart 2005 p. 822). A more robust method for testing for the LOP therefore lies in the VECM system analysis.

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

$$\boldsymbol{\beta}' = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ -1 & 0 & \cdots & 0 \\ 0 & -1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & -1 \end{bmatrix} \qquad (4)$$

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 for 5 grades of radiata pine logs across four New Zealand regions. 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.

<insert table 1 about here>

Unit root (Elliot *et al.* 1996) and stationary tests (Kwiatkowski *et al.* 1992) conducted by Niquidet and Manley (2007) suggest that all of the prices are non-stationary I(1) processes, with the exception of pulp prices on the North Island.[1] Seeing that the Johansen and Engle-Granger procedures rely on prices being I(1), these North Island pulp prices were excluded from our co-integration 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 do this because of the simplicity and flexibility associated with this approach and for the sake of

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

comparison with the more complex, yet robust, Johansen method. Also, Kennedy (2003) suggests 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).

<Insert Table 2 about here>

The results, in general, do not support full co-integration of prices across regional markets. The exception to this being the export grade KS where the results essentially support full integration. There also appears to be co-integration on the North Island for pruned logs and on the South Island for pulpwood. Lastly, a co-integration relation exists 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.[2] These results are reported in table 3.

<Insert Table 3 about here>

The t tests reject the LOP for the grades P1, P2 and Pulp. However, the LOP is supported for the export price series KS (only the weak LOP between the NNI and

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

SNI). However, these t tests should be taken in context as endogeneity problems discussed earlier could affect their properties, particularly for KS where there is more than one co-integrating relationship. We therefore turn next to the Johansen system method.

In general, the levels data were trending slightly downward, but often not significantly (Niquidet and Manley 2007). We consequently 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. Only the export grade KS is fully integrated across all regions, as the trace test suggests that there are three co-integrating relationships among the four price series. Pulp prices between the two regions on the South Island also appear to be integrated and there exists a single co-integrating relationship among the P2 prices. However, for all the other domestic log grades, markets are 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 $\mathbf{\Pi}$.

<insert Table 4 about here>

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, 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 are found.

Perhaps most notably, the trace test now points to a co-integrating relationship among the prices for the domestic 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.

<insert Table 5 about here>

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 $\boldsymbol{\beta}$ matrix and their weights $\boldsymbol{\alpha}$ from the unrestricted co-integration model of KS prices (equation 3).

<insert Table 6 here>

The matrix was then restricted according to equation 4 to reflect the LOP hypothesis. We fail 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) 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.

Also, one must be aware of the limitations associated with co-integration analysis. Barrett (1996) shows that co-integration is not a necessary or sufficient condition for market integration. He emphasises the need for analysis to move beyond price data, and incorporate trade flows and transaction costs. Similarly, McNew and Fackler (1997) advise caution in using co-integration for analysing spatial price behaviour. They show 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 and Li 2002, Hansen and Seo 2002, Sephton 2003) which to date have not yet spilled over into the forest economics literature.[3] 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 there drawbacks, as they use seemingly arbitrary distributional assumptions (Barrett 2005). Future research may also proceed by simultaneously estimating both integration and transaction costs. However, these "threshold" integration models tend to be computationally expensive as the likelihood function is non-differentiable (Balcombe *et al.* 2007). We also have a general concern about aggregation of prices within a region, as the regions studied in this paper are large and include mills at different localities.

[3] A possible exception to this has been work done by Zhou and Buongiorno (2005). While they do not explicitly incorporate transaction costs between regions, their model allows for spatial dependence between regions.

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 also 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). The degree of concern will depend on the purpose of the analysis. However, MAF 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.

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 localized wood quality factors.

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TABLES

Table 1 – New Zealand log grade specifications

	P1	P2	KS	S1/S2	Pulp
Pruning	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
Source: Adapted from Agri-fax					

Table 2 – Engle Granger co-integration tests

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

Note: Unit root rejected at * , 5%; **, 1% using Davidson and MacKinnon (1993) critical values

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

Grade	Dependent Variable	Explanatory Variables		R^2
P1	NSI	SNI	Constant	
		0.493†	2.502*	0.785
	NNI	SNI	Constant	0.975
		1.192†	-.994*	
P2	SSI	SNI	Constant	
		0.831†	0.610*	0.708
	NNI	SNI	Constant	
		1.239†	-1.224*	0.973
KS	NSI	SSI	Constant	
		0.984	0.074	0.943
	NSI	SNI	Constant	
		1.012	-0.076	0.882
	SSI	NNI	Constant	
		1.020	-0.128	0.897
	SSI	SNI	Constant	
		1.001	-0.040	0.888
	NNI	SNI	Constant	
		0.977	0.107*	0.990
Pulp	NSI	SSI	Constant	
		0.444†	2.094*	0.192
	NNI	SNI	Constant	
		0.765†	0.920*	0.719

Note: *, significantly different than zero at 5% level; †, significantly different than one at 5% level

Table 4 – Johansen's trace test results, lag selection by Akaike Information Criterion

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

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

Table 5 – Johansen’s trace test results, lag selection by Schwarz Information Criterion

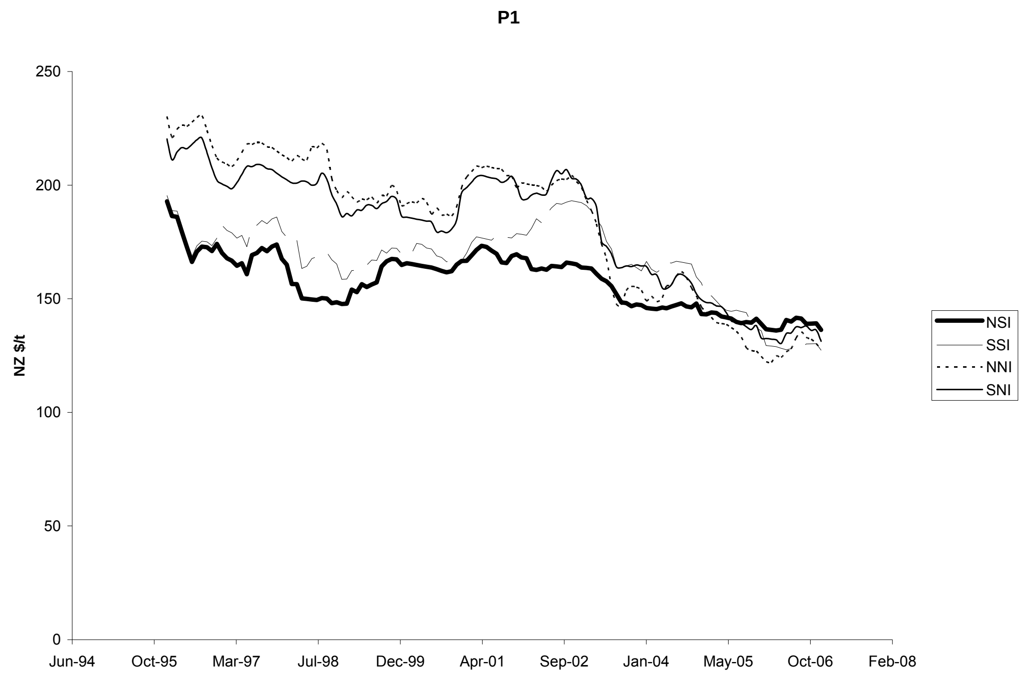
Log Grade	Lag	Null hypothesis	Trace statistic	5% critical value
P1	1	r=0	55.13*	53.12
		r≤1	34.08	34.91
		r≤2	15.49	19.96
		r≤3	3.79	9.24
P2	1	r=0	57.16*	53.12
		r≤1	28.77	34.91
		r≤2	11.15	19.96
		r≤3	3.26	9.24
KS	1	r=0	81.47*	53.12
		r≤1	46.02*	34.91
		r≤2	18.52	19.96
		r≤3	4.31	9.24
S1/S2	1	r=0	45.04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

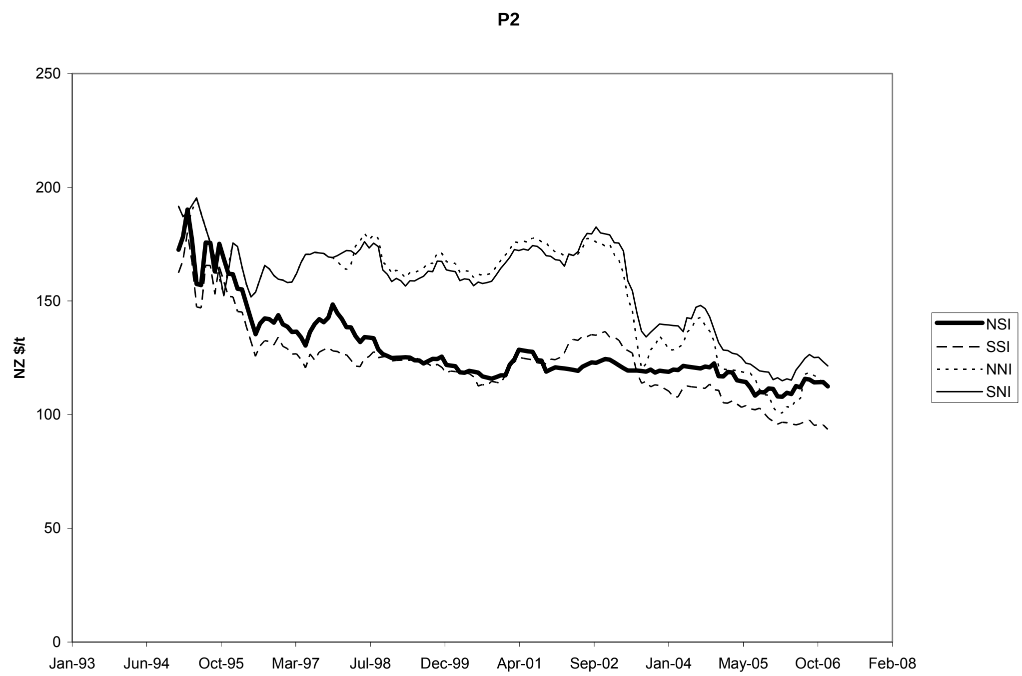
* Reject null hypothesis at 5% significance level (case 2)
Critical values from Osterwald-Lenum (1992)

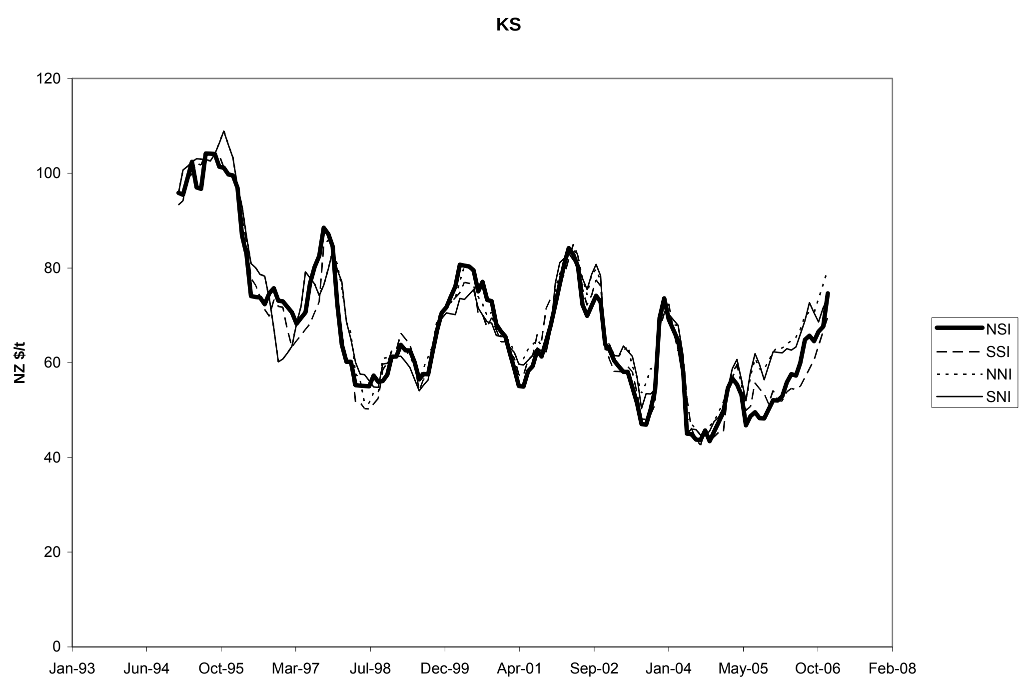
Table 6 – Normalized eigenvectors, β, and their weights, α, obtained from co-integration equation 3.

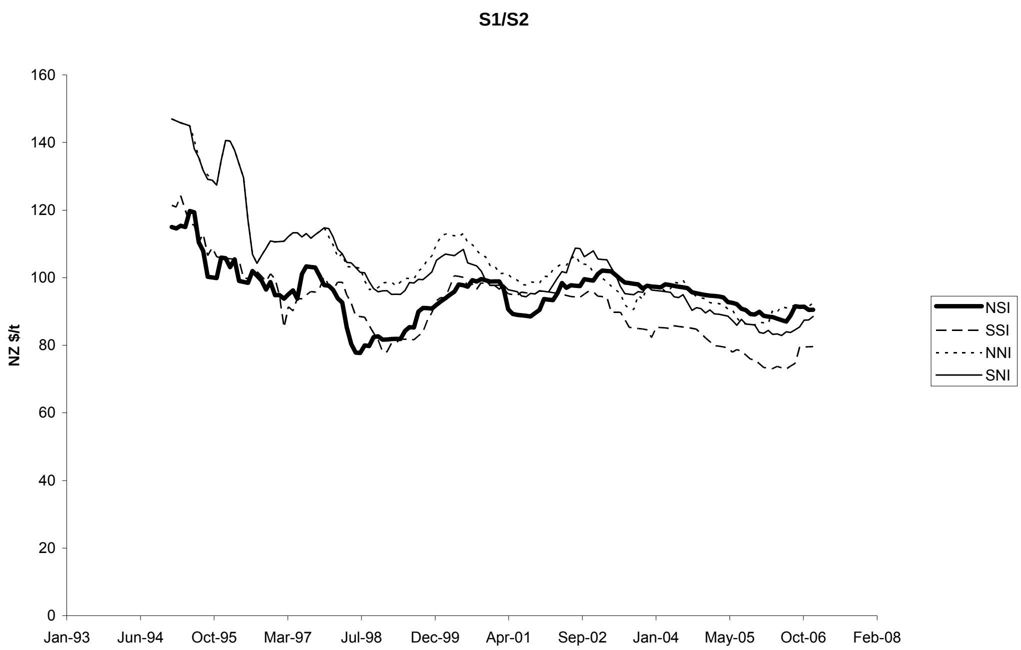
	Eigenvectors			Weights		
Region	β_1	β_2	β_3	α_1	α_2	α_3
NSI	1	0.000	0.000	0.014	-0.157	0.617
SSI	0.000	1	0.000	0.270	-0.380	0.387
NNI	0.000	0.000	1	0.147	-0.042	0.196
SNI	-1.139	-1.095	-1.031	0.137	-0.024	0.465

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

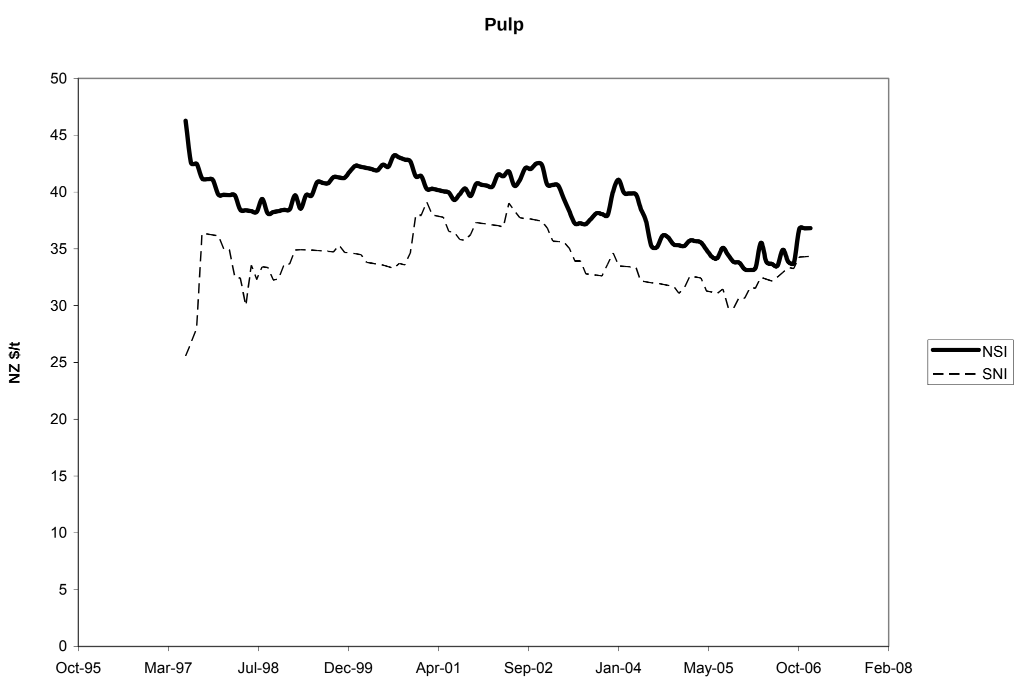



P2
250
200
150
100
50
0
NZ $/t
Jan-93
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
NSI
SSI
NNI
SNI


KS
120
100
80
60
40
20
0
NZ $/t
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
160
140
120
100
80
60
40
20
0
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