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Testing Market Integration in the Canadian Softwood Lumber Markets[1]

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Johansen 共積分을 利用한 一價의 原則 分析 : 캐나다 針葉樹材 市場 適用[1]

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ABSTRACT

This paper investigates the empirical validity of market integration for the five softwood lumber markets in Canada : Atlantic, Quebec, Ontario, Prairie, and British Columbia (BC). The Augmented Dickey-Fuller (ADF) tests of monthly price series for the period 1987 : 10-1998 : 11 reveal strong evidence for the presence of a unit root in each series. Accordingly, the Johansen cointegration technique is used to test for the law of one price in the five regional markets. Results show that the law holds in the pair, three, four, and five markets, supporting the hypothesis of market integration.

Key words : Johansen cointegration analysis, law of one price, stationarity

요 약

본 硏究는 Johansen 共積分 分析 (cointegration analysis)을 이용하여 캐나다 (Canada) 內의 5개 地域 (Atlantic, Quebec, Ontario, Prairie, British Columbia) 針葉樹 製材 (softwood lumber) 價格의 一價의 原則 (law of one price)이 성립하는지 究明하는데 그 目的이 있다. 1987년 10월부터 1998년 11월까지의 月刊 시계열자료를 이용하였으며 單位根 檢證法 중 가장 많이 사용되는 Augmented Dickey-Fuller (ADF) 검증법을 이용한 결과 연구에 이용된 모든 수준변수 (level variables)들은 不安定的 (non-stationary)이지만 차분변수 (differenced variable)들은 안정적이므로 공적분 분석의 先決條件이 만족되었다. Johansen 공적분 분석결과 캐나다 (Canada) 內의 5개 地域 針葉樹 製材價格의 一價의 原則 (law of one price)이 성립되는 것으로 나타났다.

INTRODUCTION

Integrated markets are defined as markets in which prices of differentiated products do not behave independently (Diakosavvas, 1995). This is known as the law of one price (LOP). The distinction between integrated and non-integrated markets is important for the formulation of empirical models of demand and supply at the aggregate level. Markets which are independent must be modeled in a disaggregate manner, while markets which are integrated may be modeled to aggregate analysis.

Several researchers have tested LOP for forest products with varying results. For example, Buongiorno and Uusivuori (1992) tested LOP by applying a Dickey-Fuller type bivariate method to

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U.S. pulp and paper exports to Western European countries and Japan, and found support for LOP between two markets. This method, however, does not permit testing for LOP for more than two markets simultaneously. The Johansen cointegration technique (Johansen 1988, 1991; Johansen and Juselius, 1990) recently developed has allowed researchers to investigate LOP in several markets simultaneously. Using this technique, Jung and Dorroodian (1994) tested LOP for four regional softwood lumber markets in the United States; Thorsen (1998) investigated the Nordic markets for Norway spruce timber prices; Nagubadi and Munn (1997) tested the law in the hardwood and pine pulpwood stumpage markets of the six states in South Central United States; and Toppinen and Toivonen (1998) tested LOP for roundwood market in Finland. All these studies have found support for LOP. However, in a study by Hanninen *et al* (1997) on newsprint import to the United Kingdom and Germany, and by Hanninen (1998) on soft sawnwood import to the United Kingdom, the authors found no support for LOP.

Most analyses of supply and demand for Canadian softwood lumber assume that lumber markets are integrated at some level. For example, Manning (1975), Adams and Haynes (1980), Adams and Haynes (1985), Adams *et al* (1986), Singh and Nautiyal (1986), Shama (1986), Jacques *et al* (1986), and Gellner *et al* (1991), in their econometric studies of lumber, have treated the entire Canada as a single market. However, the existence of a national lumber market in Canada has not been formally tested. Furthermore, since barriers to the entry of Canadian lumber have varied by province of origin since 1996 (Trade and Environment Database, 1999), it is possible that a previously integrated market become less integrated since that time. This is due to the fact that a Canada-US lumber trade agreement in that year was based upon the assumption that different levels of resource subsidies existed in different parts of Canada. For example, since a large portion of the Atlantic region forests are privately owned, it was accepted by the US that subsidies in that region are negligible and that stumpage prices fairly reflected the value of the resource. The purpose of this study is, therefore, to test the hypothesis of integration of softwood lumber markets in Canada.

This paper is structured as follows. The second section is devoted to the data and methodology, the third section to the analysis of the empirical results, and the final section to some concluding remarks.

DATA AND METHODOLOGY

Monthly industrial product price indexes (1992 : 100) for five softwood lumber Canadian markets -- Atlantic, Quebec, Ontario, Prairies, and BC-- are used in this study. Fig. 1 shows a map of Canada which consists of ten provinces and three territories. The Atlantic regional market consists of four small provinces, namely New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland. The three large provinces - Quebec, Ontario, and British Columbia - constitute their own regional markets. The central regional of Prairie consists of Alberta, Saskatchewan, and Manitoba. The data are from Statistic Canada Category 62-011 (also available in CASIM - Canadian Socio-economic Information Management System) for the period from October 1987 to November 1998. All the analyses are carried out using nominal price series in logarithms. The logged price series are examined because, in demand studies, the use of prices in logarithms allows direct elasticity estimates. The use of nominal prices instead of real prices also warrants an explanation. The purpose of this study is to examine price co-movements across regional markets. Since price indexes across Canada move closely, the co-movements among nominal prices reflect those among real prices. In fact, in the literature, both nominal and real prices have been used to examine market integration. (eg. Buongiorno and Uusivuori, 1992; Jung and Dorroodian, 1994; Nagubadi and Munn, 1997; Thorsen, 1998 used nominal prices; and Toppinen and Toivonen, 1998; Hanninen *et al*, 1997; Hanninen, 1998 used real prices, respectively)

According to Engle and Granger (1987), the law of one price holds if the market prices are cointegrated. Thus, testing LOP requires testing if two, three, four, and five price series are cointegrated. To this end, the Johansen cointegration procedure

Fig. 1. Map of Canada

Note : Prairie region consists of Alberta, Saskatchewan, and Manitoba, and Atlantic region consists of New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland.

is followed. The procedure first determines the cointegration rank of the price data, which is the number of cointegration vectors in the data. If the rank is four, the law of one price holds for all five markets simultaneously. In summary, testing for market integration involves two steps : 1) unit root tests for the order of integration of all five price series, and 2) cointegration tests for the law of one price for the two, three, four and five markets.

Cointegration analysis

The Johansen cointegration technique is based on maximum likelihood estimation of a vector autoregressive (VAR) system. Given a $N \times 1$ vector of variables P_t (in our case, the variables are the prices in logarithms) and considering a VAR model of order q :

$$P_t = A_1P_{t-1} + A_2P_{t-2} + \cdots\cdots + A_qP_{t-k} + \varepsilon_t \quad \text{(2)}$$

where P_t is a $N \times 1$ vector of non-stationary, I(1) variables, A_1, A_2, $\cdots$ and A_k are $N \times N$ parameter matrices of coefficients to be estimated, and optimum numbers of k are determined by the likelihood ratio (LR) test. ε_t is a $N \times 1$ vector of errors that are uncorrelated with their own lagged values and uncorrelated with all other variables. The above VAR model (2) can be represented as :

$$\Delta P_t = \Gamma_1 \Delta P_{t-1} + \Gamma_2 \Delta P_{t-2} + \cdots\cdots + \Gamma_{k-1} \Delta P_{t-k} + \Pi P_{t-1} + \varepsilon_t \quad \text{(3)}$$

where $\Pi = -(I - A_1 - A_2 \cdots\cdots - A_k)$ (I is an identity matrix), and

$\Gamma_i = -(A_{i+1} + A_{i+2} + \cdots\cdots + A_{i+k})$, $i = 1, 2, \cdots k-1$,

The matrix Π, whose dimensions are $N \times N$, can be expressed as a product of two matrices : $\Pi = \alpha\beta'$, where α indicates the speed of adjustment to equilibrium, and β is the cointegrating vector. Since matrix Π has N columns, its maximum rank is N and its minimum rank is zero. Therefore, our model has N+1 possible cases, which are grouped into three as follows :

Case 1 : $r(\Pi) = 0$

This result implies that a VAR system of equations where all the variables are I(1) can be estimated in first differences without any loss of relevant information. Since in such case all variables in the estimated equations are stationary, test statistics such as the Student-t test, the LM test and so on, are valid.

Case 2 : $r(\Pi) = N$

If $r = N$, that is the matrix Π has full rank, this implies that all the N variables in P_t are stationary.

Case 3 : $0 < r(\Pi) < N$

If $0 < r(\Pi) < N$, that is, the matrix $r(\Pi)$ has a reduced rank, then there are (N-r) linear combinations of P that act as a common stochastic trend, and r cointegrated linear combination.

In summary, the hypothesis of cointegration is formulated as the hypothesis of reduced rank of the coefficients matrix Π, which can be decomposed to : $\Pi = \alpha\beta'$ under the Johansen maximum likelihood procedure, where β is $N \times r$ matrix of cointegrating vectors and α is the $N \times r$ matrix of "weighting elements". The stationary relations $\beta' P$ are referred to as the cointegrating relations. The estimate of β' is obtained by solving an eigenvalue problem, whose solution is represented by the eigenvectors β_i and the eigenvalues Ω_i.

As for testing cointegration, the Johansen approach is based on the likelihood ratio test of the null hypothesis of N-r unit-root against the alternative of N-r-1 unit root. The likelihood ratio test, called the trace test, has a test statistic : $Q= -T \sum_{i=r+1} Ln(1-Q_i)$, where Q_i are the ordered largest eigenvalues.

EMPIRICAL RESULTS

A prerequisite for the cointegration analysis is that the data series for each variable included in the model be non-stationary and be integrated of the same order with similar statistical properties. To this end, the Augmented Dickey-Fuller (ADF) test is used. The ADF test procedure involves estimating the following regression :

$$\Delta p_t = \alpha + \beta \Delta p_{t-1} + \gamma_1 \Delta p_{t-1} + \gamma_2 \Delta p_{t-2} + \cdots\cdots + \gamma_{q-1} \Delta p_{t-q+1} + e_t \quad \cdots\cdots (1)$$

where p_t is the variable of concern (ie. an individual price), $\Delta p_t = p_t - p_{t-1}$. The null hypothesis that p_t has a unit root implies $\beta=0$ in equation (1). So, testing whether $\beta=0$ in equation (1) means testing the null hypothesis that p_t has a unit root against the alternative that it is integrated of order zero. The optimal lag length is chosen based on the Akaike's final prediction error (FPE) criterion. The critical values are found in MacKinnon (1991) for any sample size and for any number of dependant variables.

The ADF test is performed on the levels of logged prices under examination. The results are presented in Table 1. Based on the critical values reported by MacKinnon (1991), the null hypothesis is not rejected for all variables at the 5 percent significance level, which means that all prices in logarithms are non-stationary.

However, the presence of non-stationarity in the variables does not guarantee that the variables are integrated of order one, I(1), which means that a variable is not stationary in the level, and stationary after first differentiation. They are possibly integrated of higher order. If a variable is I(1), then the first difference will be stationary. On the other hand, if a variable is integrated of higher order, then the first difference will not be stationary. Most importantly, cointegration analysis should be conducted on variables with the same order of integration. Otherwise, the tests are invalid. Therefore, further tests to identify whether the variables involved are integrated with the same order are merited. The ADF test is then done on the first difference of the variables.

The last column of Table 1 presents the results of the ADF unit root test for each first-differentiated variable under examination. Based on the critical values reported by MacKinnon (1991), all variables concerned appear to be stationary in the first difference at the 5 percent significance level. Thus, we conclude that all variables involved are not stationary in the level, but stationary in the first difference, which means that the pre-condition for cointegration analysis is satisfied.

Accordingly, Johansen's trace test is carried out to find the cointegrating vectors for pair-wise lumber price of adjacent markets in Canada. The result of the trace test is given in Table 2 along with the 5 and 1 percent quantiles of the appropriate limiting distribution calculated by Osterwald-Lenum (1992).

All trace cointegration tests lead to the rejection of the null hypothesis of r=0 against the alternative

Table 1. Test Results using the ADF Unit Root Test

Price Variables	ADF-test statistic	No. of lags	ADF-test 1st difference
p_{BC}	-1.1665	4	-6.0655***
$p_{PRAIRIE}$	-1.0723	4	-6.7181***
$p_{ONTARIO}$	-0.8347	4	-6.1531***
p_{QUEBEC}	-0.9973	4	-6.6748***
$p_{ATLANTIC}$	-0.7936	4	-5.6948***

Note : Critical values are -2.578 at 10 percent level * of significance, -2.883 at 5 percent level ** of significance, and -3.480 at 1 percent level *** of significance.

Table 2. Cointegration Test for Pair-wise Markets

Markets / H_0	Eigenvalues	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value
Atlantic and Quebec				
r = 0	0.142544	24.557*	19.96	24.60
r ≤1	0.029047	3.950	9.24	12.97
Quebec and Ontario				
r = 0	0.139607	21.611*	19.96	24.60
r ≤1	0.029047	1.462	9.24	12.97
Ontario and Prairie				
r = 0	0.136292	23.560*	19.96	24.60
r ≤1	0.014761	1.993	9.24	12.97
Prairie and B.C.				
r = 0	0.21733	35.932**	19.96	24.60
r ≤1	0.022770	3.086	9.24	12.97

Note : ** and * indicate statistical significance at 5 and 10 percent, respectively.

r≤1 while the null of r≤1 against r≤2 cannot be rejected at the 5, or 1 percent level. Therefore, there is one cointegrating relationship among each of the pair variables under estimation, indicating that the LOP holds for each adjacent pair lumber markets.

Next, we carried out Johansen's trace test to find the cointegrating vectors for three adjacent lumber markets in Canada. Table 3 gives the results of the trace tests which shows the rejection of the null hypothesis of r≤1 against the alternative r≤2 while the null of r≤2 against r≤3 cannot be rejected at the 5, or 1 percent level. Therefore, it is concluded that there are two cointegrating relationships among each pair variable under estimation, indicating that LOP hold for each adjacent three lumber markets.

To test for market cointegration in the four

Table 3. Cointegration Tests for Three Markets

Markets / H_0	Eigenvalues	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value
Atlantic, Quebec and Ontario				
r = 0	0.201702	46.250**	24.31	29.75
r ≤1	0.163400	16.064*	9.24	16.31
r ≤2	0.107178	3.348	3.84	6.51
Quebec, Ontario and Prairie				
r = 0	0.177164	35.529**	24.31	29.75
r ≤1	0.090661	16.399**	9.24	16.31
r ≤2	0.017992	2.433	3.84	6.51
Ontario, Prairie and B.C.				
r = 0	0.141138	33.15**	24.31	29.75
r ≤1	0.077489	12.765*	9.24	16.31
r ≤2	0.014498	1.956	3.84	6.51

Note : ** and * indicate statistical significance at 5 and 10 percent, respectively.

adjacent lumber markets in Canada, Table 4 shows the results of the trace test with the 5 and 1 percent quantiles of the appropriate limiting distribution. All trace cointegration tests lead to the rejection of the null hypothesis of r≤2 against the alternative r≤3 while the null of r≤3 against r≤4 cannot be rejected at the 1, or 5 percent level. Therefore, we infer that there are three cointegrating relationships among each adjacent three variables under estimation, concluding that LOP holds for the four lumber markets.

Finally, to find out if all five lumber markets are integrated, we conducted the trace test involving all five price series. Once again, the trace tests reported in Table 5 lead to the rejection of the null hypothesis of r≤3 against the alternative r≤4 while the null of r≤4 against r≤5 cannot be rejected at the 5 percent level. Therefore, we infer that there are four cointegrating relationships among the variables under estimation. The results show that all markets are integrated simultaneously, indicating that LOP for Canadian lumber market holds simultaneously.

As an alternative methodology, Stifler and Sherwin (1985) based their empirical analysis of market integration on analysis of correlation coefficients for products hypothesized to be in the same market. Correlation coefficients provide an index measure of market integration; values near 1.0 suggest products are clearly in the same market, and values near zero suggest products are clearly in different markets. The correlation coefficients for the price series for each market were computed as a measure of the market integration between each market in Canada. High significance in the correlation coefficient will imply that corresponding lumber markets in Canada are integrated. Table 6 reports correlation coefficients of different pairs of lumber prices in Canada. These correlation coefficients are very high between each lumber price pairs in Canada. These results suggest further that LOP holds in Canadian lumber markets.

Table 4. Cointegration Tests for Four Markets

Markets / H_0	Eigenvalues	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value
Atlantic, Quebec, Ontario and Prairie				
r = 0	0.194246	59.972**	47.21	54.46
r ≤1	0.163400	31.030*	29.69	35.65
r ≤2	0.107178	15.641*	15.41	20.04
r ≤3	0.107178	2.520	3.76	6.65
Quebec, Ontario Prairie and B.C.				
r = 0	0.217493	64.402**	47.21	54.46
r ≤1	0.143645	31.538*	29.69	35.65
r ≤2	0.056278	15.758*	15.41	20.04
r ≤3	0.022114	2.997	3.76	6.65

Note : ** and * indicate statistical significance at 5 and 10 percent, respectively.

Table 5. Cointegration Tests for Five Markets

Markets / H_0	Eigenvalues	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value
r = 0	0.210799	86.637**	68.52	76.07
r ≤1	0.163400	54.915*	47.21	54.46
r ≤2	0.107178	31.008*	29.68	35.65
r ≤3	0.086856	15.817*	15.41	20.04
r ≤4	0.026809	3.641	3.76	6.65

Note : ** and * indicate statistical significance at 5 and 10 percent, respectively.

Table 6. Correlation of Canadian Lumber Prices

	PBC	PPRAIPIE	PONTARIO	PQUEBEC	PATLANTIC
PBC	1.000				
PPRAIPIE	0.970	1.000			
PONTARIO	0.975	0.989	1.000		
PQUEBEC	0.961	0.982	0.989	1.000	
PATLANTIC	0.897	0.909	0.936	0.932	1.000

CONCLUSIONS

This paper has investigated market integration in lumber markets in Canada. Tests for stationarity reveal strong evidence for the presence of a unit root in levels of the univariate price series in logarithms. Using Johansen cointegration tests and correlation coefficients, we find that the law of one price holds for the five softwood lumber markets as well as any subsets of these markets in Canada. The markets are indeed integrated as assumed by a number of researchers in studying the Canadian lumber markets, and this integration holds despite the differences in access to the U.S. markets enjoyed by the Atlantic region as mentioned before.

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