CANADIAN NEWSPRINT IN THE UNITED STATES: A MULTIVARIATE COINTEGRATION ANALYSIS

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ABSTRACT

In this paper, Johansen multivariate cointegration tests are adopted to investigate the U.S. demand for Canadian newsprint using monthly data from May 1988 to December 1996. Preliminary data analysis shows that all data are non-stationary which implies that previous results based on simple ordinary least squares are spurious. Johansen multivariate cointegration techniques allow for identifying a long-run relationship as well as a short-run relationship via an error correction model. Among the determinants are the export price of Canadian newsprint to the U.S., the exchange rate between the two countries, U.S. personal disposable income, and U.S. newsprint price.

Keywords: Cointegration, error correction mechanism, demand, exports, newsprint.

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INTRODUCTION

Canada is the world's leading producer and exporter of newsprint. According to the Canadian Pulp and Paper Association (1997), Canadian newsprint exports accounted for nearly 49.3 percent of all global exports (17,435,000 tonnes) in 1996. In the same year, Canada's leading customer for newsprint, the U.S. received almost 68 percent (5,263,000 tonnes) of the newsprint exported from Canada. This represented about 50 percent of U.S. consumption. Not surprisingly, Canadian newsprint exports to the U.S. have been a major source of revenue for the newsprint industry in Canada. According to statistics released by Natural Resource Canada (1996), earnings from newsprint exports to the United States were about 4.677 billion dollars in 1995, which accounted for about 20.6 percent of the value of forest products exported (22.680 billion dollars) to the U.S..

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Despite the importance of Canadian newsprint in the U.S. market, there have been few studies on Canadian newsprint trade between the U.S. and Canada. The first export demand study was done by Ghebremichael (1989), who estimated the demand for newsprint exported to the U.S. from Ontario, Canada. Using ordinary least squares (OLS) estimation and annual data from 1966 to 1986, this study found that Ontario newsprint exports had a cross-price elasticity of –1.45 with respect to U.S. newsprint (thus indicating hard-to-believe complementarity), an income elasticity of 3.95, and cross-price elasticities with respect to writing and printing paper, and market pulp of 2.89 and –0.32, respectively. The strength of the Canadian dollar had a negative impact on the demand for Ontario's newsprint in the American market with an elasticity of –0.31.

The only other significant study is Baker (1991). Using an Almost Ideal Demand System (AIDS) model and data for the period of 1966 to 1987, Baker found that income and export price elasticities were 0.81 and –0.92 respectively. However, this study specified the U.S. demand for Canadian newsprint as a function of only two variables; U.S. income, and the U.S. import price of Canadian newsprint. The exclusion of other variables *a priori* may have caused biased estimates.

While there have been few studies on newsprint, there have been several on forest products. Examples are Nordvall (1996), Chou & Buongiorno (1984), and Buongiorno *et al.* (1979, 1988). These studies are mentioned because they serve as a basis for selecting appropriate variables and formulating the model of export demand for newsprint in this paper.

Most previous studies on newsprint demand or forest products applied simple OLS approach to the time series data. However, it is now well-known (Nelson & Plosser, 1982) that most time-series economic variables are non-stationary. Regression with non-stationary variables is spurious and thus leads to unreliable estimates.

The purpose of this study is to employ the recently developed cointegration technique to estimate the demand for Canadian newsprint using monthly data from May 1988 to December 1996. Because of the use of cointegration techniques and monthly data, more accurate and updated elasticities of Canadian newsprint demand to price, income, and other variables are obtained. The paper proceeds as follows: We start by introducing the model, defining the variables and explaining the data. Then we outline the Johansen cointegration procedure, and present the results We end the paper with our conclusions and some policy implications.

To briefly summarize the results, we found that among the determinants of Canadian newsprint exports to the U.S. are the export price of Canadian newsprint to the U.S., the exchange rate between the two countries, U.S. personal disposable income, and U.S. newsprint price. We found that all variables are non-stationary and there exists one cointegrating vector among the variables. The demand elasticities with respect to export price of Canadian newsprint , the exchange rate, income and U.S. newsprint price are respectively –0.92, –1.46, 1.27 and 0.76 for the long run and –0.38, –0.83, 0.93, and 0.81 for the short run. As explained later in this paper, these results are consistent with standard economic theory.

MODEL

A simple trade model, involving a single commodity and two countries, is used to establish theoretical relationships among the variables. Canada is the exporter while the United States is the importer. Following the literature, the U.S. import demand for Canadian newsprint (Q) is hypothesized to depend on the export price of Canadian newsprint (P_c), the exchange rate between United States and Canada (E = \$US/CAN), U.S. newsprint price (P_{us}), and U.S. personal disposable income (Y). The reduced demand equation can be expressed as follows:

$$Q = \beta_0 + \beta_1 P_c + \beta_2 E + \beta_3 P_{us} + \beta_4 Y + \varepsilon_t \qquad (1)$$

where ε_t is the error term and β_1, β_2, β_3, and β_4 are the coefficient parameters to be estimated. All variables are in logarithmic-form.[1] The signs of these coefficients follow from

[1] The double logarithmic-form is a standard econometric specification in demand studies since the coefficients can be conveniently interpreted as elasticity measures. See, for example, Ghebremichael (1989).

standard demand theory. In particular, $\beta_1 < 0$ since an increase in the export price of Canadian newsprint decreases the U.S. demand for it. Similarly, $\beta_2 < 0$ because an appreciation of the Canadian dollar (i.e., E rises) increases the price of Canadian newsprint resulting in a decrease of Canadian newsprint demand in the United States due to law of demand. The higher the personal disposable income in the U.S., the higher is the demand for Canadian newsprint ($\beta_3 > 0$). Finally, $\beta_4 > 0$ since a higher domestic price of newsprint in the U.S. market will make Canadian newsprint relatively cheaper thus more competitive in the U.S. market.

DATA

The study is based on monthly data for 1988:5 – 1996:12. Canadian newsprint exported to the United States is expressed in "thousands of cubic meters" of newsprint, and is compiled from Statistics Canada (HS:48010000). U.S. personal disposable income, expressed in U.S. dollars, is converted to its real value using the consumer price index (CPI) as the deflator and is obtained from the Bureau of Economic Analysis of the United States Department of Commerce.

The CPI [1989=100] is taken from the Survey of Current Business published by the U. S. Department of Commerce. The exchange rate is expressed as U.S. dollars per Canadian dollar and is from various issues of the Bank of Canada Review. The export price of Canadian newsprint is calculated as the export value (in Canadian dollar) of newsprint divided by the export quantity of newsprint from Canada to the U.S. and the data are from the Statistics Canada (HS:48010000). The export price of newsprint, from the *Statistics Canada* (Category No. 62-556, 62-558), is converted to its real value by using the Industrial Product Price Index (all commodities) [1992=100] as the deflator.

The U.S. newsprint price, which is the producer price index of newsprint, is converted to its real value by using the Producer Price Index (all commodities) [1989=100] as the deflator. The data are taken from the *Bureau of Labor Statistics of the United States*, U.S. Department of Labor. The Producer Price Index (all commodities) data are from the *Survey of Current Business* published by the U.S. Department of Commerce.

TABLE 1. TEST RESULTS USING THE ADF UNIT ROOT TEST.

Variables	ADF-Test Statistic	No. of Lags	ADF-Test 1st Difference
Q	–0.50589	4	-5.88651^{***}
P_c	–0.44030	4	-4.26509^{***}
E	0.77558	1	-6.97837^{***}
Y	–0.29294	1	-5.03409^{***}
P_{us}	–0.84979	1	-3.02419^{***}

Notes: Critical values are –1.62 at the 10 percent level**, –1.94 at the 5 percent level****, and –2.59 at the 1 percent level**** *(P_c = export price, E = exchange rate, Y = U.S. personal disposable income, P_{us} = U.S. newsprint price).*

JOHANSEN COINTEGRATION ANALYSIS

Before the cointegration analysis can be carried out, it is necessary to test whether the data are stationary. To this end, the Augmented Dickey-Fuller (ADF) test is used.[2] Table 1 shows the results of the ADF test for both the level (in column 2) and the first-difference of variables (in column 4). The results in column 2 indicate that the null hypothesis of a *unit root* is not rejected for all variables in levels at the 10 percent significance level. Thus the variables are non-stationary.

On the other hand, as shown in column 4 of Table 1, all variables are stationary in the first difference at the 1 percent significance level. We therefore conclude that all variables, dependent and independent, are integrated of order one (denoted by $I(1)$). Consequently, employing traditional OLS estimation technique will lead to biased estimates and misleading hypothesis tests. To address this concern, we adopt the cointegration analysis and error correction mechanism (ECM) within which both the long run and short run demand equations can be estimated.

To test for a cointegration or a long-run relationship between the dependant and independent variables, most researchers first regress the levels of the variables under con-

[2] See Said & Dicky (1984). The optimal lag length is chosen based on the Akaike's final prediction error (FPE) criterion. The critical values are found in MacKinnon (1991).

sideration using OLS, and then test for stationarity of the residuals using a unit root test such as the ADF test. If the residuals are stationary, the variables are cointegrated, thereby implying a long-run stationary relationship between the dependant and independent variables. Furthermore, Stock (1987) has shown that, even if the residuals are serially correlated, the parameter estimates from the long run regression are super-consistent, in the sense that they converge to their true values much faster than in the stationary case. There are, however, a number of problems associated with this simple technique as a solution to non-stationarity.

First, as Banerjee *et al.* (1986) have shown, in spite of the super-consistency property, the bias on the parameter estimates can be quite severe in small samples. Second, the estimates are not invariant to the chosen normalization, (i.e. which variable to be used as dependent variable and which to be used as independent variables). Third, when there are more than two variables involved, the possibility of multiple cointegration relationships arises. In general, there may exist up to $N-1$ stationary linear relationships among N non-stationary variables. Conducting the static OLS regression only makes it possible to estimate one of these. Finally, the OLS parameter estimates are not normally distributed if the variables are $I(1)$ processes. This makes standard inference invalid, and therefore it is not possible to test interesting hypotheses.

To address these problems, the Johansen multivariate cointegration procedure developed by Johansen (1988, 1991) and Johansen & Juselius (1990) is followed. This procedure is based on maximum likelihood estimation of a vector autoregressive (VAR) system. Given a $N\times1$ vector of variables X_t (in our case $X_t = (Q, P_c, E, Y, P_{us})_t$, $N = 5$) and considering a VAR model of order k:

$$X_t = A_1X_{t-1} + A_2X_{t-2} + \ldots + A_kX_{t-k} + \varepsilon_t\,, \qquad (2)$$

where X_t is a vector of N $I(1)$ variables, A_1, A_2, ..., and A_k are $N\times N$ parameter matrices of coefficients to be estimated, k is the optimal number of lags determined by the likelihood ratio (LR) test, and ε_t is a $N\times1$ vector of errors that may be contemporaneously correlated with each other but are assumed to be uncorrelated with their own lagged values as well as all of the right-hand side variables. Using $\nabla = 1 - L$, where L is the lag operator, the above VAR model can be represented by the following ECM expression:

$$\nabla X_t = \Gamma_1 \nabla X_{t-1} + \Gamma_2 \nabla X_{t-2} + \ldots + \Gamma_{k-1} \nabla X_{t-k+1} + \Pi X_{t-k} + \varepsilon_t, \quad (3)$$

where $\Pi = -(I - A_1 - A_2 - \ldots - A_k)$ (I is an identity matrix), and $\Gamma_i = -I + A_1 + A_2 + \ldots + A_i$, $i = 1, 2, \ldots, k-1$.

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 (i.e., ECM component), and β is the cointegrating vector. Since matrix Π has 5 columns, its maximum rank is 5 and its minimum rank is zero. Therefore the model has 5 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 which are stationary (Orden & Fisher, 1991). Thus, test statistics such as the Student-t test and the F- test remain valid.

Case 2: $r(\Pi) = 5$

If $r = 5$, that is the matrix Π has full rank, this implies that all the 5 variables in X_t are stationary. In this case, OLS is appropriate.

Case 3: $0 < r(\Pi) < 5$

If $0 < r(\Pi) < 5$, that is, the matrix $r(\Pi)$ has a reduced rank, then there are $(N - r)$ linear combinations of X that act as a common stochastic trend, and r cointegrated linear combinations.

Summing up, the hypothesis of cointegration is formulated as the hypothesis of reduced rank of the coefficients matrix Π, i.e., case 3. This case can be decomposed to: $\Pi = \alpha\beta'$ under the Johansen maximum likelihood procedure, where β is the $N \times r$ matrix of cointegrating vectors and α is the $N \times rN \times r$ matrix of "weighting elements". The stationary relations $\beta' X$ are refered to as the cointegrating relations. The estimate of β' is obtained by solving an eigenvalue problem.[3]

[3] For more details, see Sarker (1993).

As for testing cointegration, the Johansen approach is based on the likelihood ratio test of the null hypothesis of $N-r$ unit roots against the alternative of $N-r-1$ unit roots. Two different tests, namely the trace statistic test and the maximum eigenvalue statistic test are used to test for cointegration relationships among the variables. If one or more cointegration vectors are found, one will proceed to estimate the short run equation (i.e., the ECM model) as in Equation 3.

However, to estimate Equation 3, we must first determine the appropriate lag length k in the VAR model. Following Lee & Chung (1995), the likelihood ratio (LR) test is used to determine the optimum numbers of lags. The LR test is based on a restricted and unrestricted regression. In this paper, the unrestricted equation is chosen with lag length $k = 8$ for each specification. This unrestricted model is then tested against a restricted model with $k = 7$ by the LR statistic, which is distributed with χ^2 (25). The test is then conducted sequentially by reducing k by one at a time from both the unrestricted and restricted models. Table 2 summarizes the results of these LR tests. The results show that the restriction of $k = 1$ against the alternative of $k = 2$ is rejected at the 5 percent level of significance, indicating that the appropriate lag length in Equation 2 is two. Therefore the appropriate lag length in Equation 3 is one.

TABLE 2. LR TEST FOR OPTIMAL LAGS IN JOHANSEN'S COINTEGRATION TEST.

H_0	H_1	LR Statistic
1	2	58.58**
2	3	22.88
3	4	13.58
4	5	16.00
5	6	18.80
6	7	19.40
7	8	8.10

*The ** indicates statistical significance at the 5% level. The critical value is 37.65.*

TABLE 3. LIKELIHOOD RATIO TEST RESULTS.

H_o: r = # of Cointegrating Vectors	Eigenvalues	Likelihood Ratio	10 Percent Critical Value	5 Percent Critical Value
r = 0	0.332774	77.05498**	64.84	68.52
r ≤ 1	0.221079	43.11203	43.95	47.21
r ≤ 2	0.126772	21.27046	26.79	29.68
r ≤ 3	0.071481	8.33972	13.33	15.41
r ≤ 4	0.010281	1.04866	2.69	3.76

*The ** indicates statistical significance at the 5 percent level.*

RESULTS

With the number of lags determined by the LR test, the two Johansen's maximum likelihood cointegration tests, the trace test and the maximum eigenvalue test, are used to find the cointegrating vectors.

The result of the trace test is given in Table 3 along with the 10 and 5 percent quantiles of the appropriate limiting distribution calculated by Osterwald-Lenum (1992). The trace cointegration test leads to the rejection of the null hypothesis of $r = 0$ against the alternative $r = 1$ while the null of $r \leq 1$ against $r = 2$ cannot be rejected at the 5 percent level. We therefore conclude that there is only one cointegrating relationship among the variables under estimation.

To confirm this, Table 4 shows the results of the maximum eigenvalue test with the 10 and 5 percent levels of significance. As with the trace test, this test does leads to the rejection of the null hypothesis of $r = 0$ against the alternative $r = 1$ while the null hypothesis of $r \leq 1$ against $r = 2$ can not be rejected at the 5 percent level, further indicating that there is only one cointegrating relationship in the variables under estimation.

Based on this cointegrating vector, the long-run elasticities of the U.S. demand for Canadian newsprint are estimated. The results, summarized in Table 5, show that

TABLE 4. MAXIMUM EIGENVALUE STATISTIC RESULTS.

H_o: r = # of Cointegrating Vectors	Eigenvalues	Likelihood Ratio	10 Percent Critical Value	5 Percent Critical Value
r = 0	0.332774	33.94295**	30.90	33.46
r ≤ 1	0.221079	22.55006	24.73	27.07
r ≤ 2	0.126772	12.95047	18.60	20.97
r ≤ 3	0.071481	7.29106	12.07	14.07
r ≤ 4	0.010281	1.04811	2.69	3.76

*The ** indicates statistical significance at the 5 percent level.*

all of the coefficients have the expected signs. In particular, the long run export-price elasticity is estimated at –0.92, which indicates inelastic demand. Interestingly, Baker (1991) produced exactly the same estimate even though using a completely different model (AIDS), data and time period.

The exchange rate elasticity of –1.46 supports the observation of the negative impact of a strong Canadian dollar on Canadian exports. A 10 percent appreciation in the Canadian dollar against the U.S. dollar would reduce newsprint exports by 14.6 percent.

TABLE 5. LONG-RUN ELASTICITIES FOR THE U.S. DEMAND FOR CANADIAN NEWSPRINT.

Explanatory Variables	Elasticities	t-values
P_c	–0.92	2.354**
E	–1.46	–3.507**
Y	1.27	3.946**
P_{us}	0.76	3.015**

*The ** indicates statistical significance at the 5 percent level. (P_c = export price, E = exchange rate, Y = U.S. personal disposable income, P_{us} = U.S. newsprint price).*

The long-run income elasticity of 1.27 means that, holding all other variables constant, a 10 percent increase in the U.S. personal disposable income is accompanied by an increase in the mean Canadian newsprint demand in the U.S. by about 12.7 percent in the long run. This elasticity is larger than the 0.81 of Baker, but much smaller than the 3.95 of Ghebremichael, who investigated the U.S. demand for Ontario's newsprint.

With respect to U.S. newsprint price, the long-run elasticity of demand is 0.76, indicating that U.S. newsprint is a substitute for imported newsprint and that a 10 percent increase in the domestic price will increase the demand for imported newsprint by 7.6 percent. In contrast, Ghebremichael (1989) found a negative cross-price elasticity of –1.45, which implies, very unrealistically, that U.S. and Canadian newsprint are complements.

These results differ from previous studies due to different methods, data, and variables used. For example, Baker(1991) specified only the U.S. income, and import-price of newsprint as independent variables to investigate the U.S. demand for Canadian newsprint in an AIDS model. Ghebremichael (1989) included U.S. income, the exchange rate, and prices for U.S. newsprint, printing and writing paper and market pulp as the independent variables in an OLS regression of the U.S. demand for Ontario's newsprint while omitting the export price of Ontario newsprint which is a key determinant in the standard demand function. Most importantly, neither Baker nor Ghebremichael conducted stationarity test though using time series data. Thus, their results are likely subject to spurious regression. In fact, when we apply simple OLS to our data sets, which are non-stationary, we find that neither the export price of Canadian newsprint (P_c) nor U.S. newsprint price (P_{us}) is significant at the five percent level. (The t-statistics are –0.2367 and 0.4127 for P_c and P_{us} respectively.) This suggests that correcting for stationarity, as done in this paper, is clearly necessary.

Turning to the short- run estimation of Equation (3) summarized in Table 6, the short-run demand elasticities with respect to the export price of Canadian newsprint, the exchange rate, U.S. disposable income and U.S. newsprint price are –0.38, –0.85, 0.93, and 0.81 respectively. The er-

Table 6 Short-run Elasticities for Canadian Newsprint Demand in the U.S..

Explanatory Variables	Elasticities	t-Values
Constant	−0.0047	−0.69153
P_c	−0.38	−1.20305
E	−0.85	−1.21775
Y	0.93	0.93232
P_{us}	0.81	2.47949**
γ	−0.39	−4.21936**
Adj. R^2	0.377	
DW	2.08	
F Value	9.78	
Probability (F-statistic)	0.000	

*The ** indicates statistical significance at the 5 percent level. Critical values are around 1.665 and 1.990 at the 10 and 5 percent level of significance, respectively, with 98 degrees of freedom. (P_c = export price, E = exchange rate, Y = U.S. personal disposable income, P_{us} = U.S. newsprint price).*

ror-correction term (γ)has a negative and statistically significance coefficient. The negative coefficient of the error correction term ensures that the long-run equilibrium is achieved.[4] However, the adjustment toward equilibrium is not instantaneous. Only 39 percent of any months' deviation from the equilibrium is corrected in the next month's growth rate of Canadian newsprint exports to the U.S..

Concerning the statistical significance of the estimated coefficients, the coefficients of the error correction term and U.S. newsprint price are individually significant at the 5

[4] With a significant negative coefficient of the error-correction term, any short-run shocks, negative or positive, will be corrected over time. Thus, the variable will return to its long-run equilibrium path.

percent level. However, the short run coefficients of U.S. personal disposable income, the exchange rate, and the export price of Canadian newsprint are not significant at the 5 percent level.

To check for the statistical adequacy of the model, we ran a series of diagnostic tests including heteroscedasticity, autocorrelation, normality and model specification. The test statistics show that the null hypotheses of homoscedasticity, no autocorrelation, normality, and no model mis-specification can not be rejected at the 5 percent level, indicating that the model is statistically adequate.[5]

CONCLUSION

The purpose of this paper has been to estimate the demand for Canadian newsprint in the United States using recently developed time series techniques of cointegration and error correction. Based on previous forest product demand studies, the export price of Canadian newsprint, the exchange rate, U.S. personal disposable income and the price of U.S. newsprint were chosen as independent variables to estimate the U.S. demand for Canadian newsprint.

Before implementing the cointegration analysis, the ADF tests were performed to check the stationarity of the data. Results showed that all of the variables under estimation are I(1), which means that the cointegration technique should be used to avoid spurious regression. To this end, we used Johansen multivariate cointegration analysis. We found that there exists one cointegrating vector among the variables, from which we derived the long run demand elasticities of −0.92, −1.46, −0.92, 1.27 and 0.76 for the export price of Canadian newsprint, the exchange rate, U.S. income and U.S. newsprint price respectively.

The Granger representation theorem (Engle & Granger, 987; Johansen, 1988) proves that, if a cointegrating relationship exists among a set of $I(1)$ series, then a dynamic error-correction representation of the data also exists. Consequently, an error correction model for the short-run demand for Canadian newsprint in the U.S. was estimated. The short-run elasticities of export price, the exchange rate, U.S.

[5] Testing results will be provided upon request.

income and U.S. newsprint price are −0.38, −0.83, 0.93, and 0.81, respectively. The export price elasticity shows that the demand for Canadian newsprint is inelastic, implying that total revenue could be raised by increasing the price of Canadian newsprint in the U.S.. On the other hand, the cross price elasticity of demand with respect to U.S. newsprint demand suggests that Canadian newsprint industry perhaps should seek cost-reducing strategies to be more competitive in the U.S. market. Our results compare favorably with previous studies on the demand for newsprint and other forest products because we applied recent cointegration techniques to monthly data by avoiding spurious regression.

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