

**COINTEGRATION OF NORTH AMERICAN SOFTWOOD LUMBER MARKETS:
DRIVEN BY DEMAND?**

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

This study utilizes the Engle-Granger two-step cointegration method to examine the correlation relationship among North American species of softwood lumber prices, wood-based panel prices, and US housing starts. The methodology employed is identical to that used by US petitioners in the latest round of the Canadian-US softwood lumber trade dispute, whereby petitioners argued that all North American species of softwood lumber were considered to be nearly perfect substitutes for one another. Tests for nonstationarity using the Augmented Dickey-Fuller unit root test, as well as our cointegration results, essentially confirm petitioner's results. We find an evidence of a long-term cointegrating relationship among the prices of North American species of softwood lumber. However, we found no clear evidence of perfect substitutability between different North American species of softwood lumber. Additional analysis reveals that a long-run equilibrium relationship exists between North American species of softwood lumber and four types of wood-based panel products, as well as US housing starts. Given that the price movements of different wood-based panel products and housing starts are highly correlated with the price movement of North American species of softwood lumber, we fail to conclude that North American softwood lumber species can be claimed as nearly perfect substitutes. Furthermore, we find that the petitioner's analysis is deficient in that it does not account for the fact that cointegration in prices among North American species of softwood lumber can be caused by common demand-side factors, such as residential construction activity.

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INTRODUCTION

The United States (US) is the world's leading producer of industrial wood products, with a production level representing nearly 25 percent of the world's total production. The US is also the world's principal consumer of wood products and it has a large consumer market for softwood lumber (Sedjo 2006). Since 1965, lumber production in the US has generally experienced an increasing trend, except for periods during the mid-1970s and early 1980s when economic slowdowns resulted in many western mills that were dependent on federal timber were forced to dramatically reduce production or cease operations. This resulted in an overall decline in lumber production, increased production by other regions, and increased levels of foreign imports (Howard 2007).

Approximately 34.52 billion board feet of softwood lumber was produced in the US in 2007 (Random Lengths Publications, Inc. 2008a). According to USDA Forest Products Laboratory (2007), the West, while the second largest overall lumber producing region, has traditionally been the largest softwood lumber producing region, with nearly 98 percent of its total production being softwood species. Softwood lumber production in the South was about 80 percent of its total production, nearly equal in volume to that of the West. The North produced 2.4 BBF softwood lumber in 2005. In general, softwood lumber production in the South and West increased during the late 1990s. Since 2000, softwood lumber production has increased in both the South and West, while the West remained as the leading softwood lumber producing region.

In 2007, lumber imports to the US from all countries totaled 18.83 BBF (Random Lengths Publications, Inc. 2008b). During the same period, exports from the US to all countries was 0.81 BBF. The difference between US exports and imports (i.e., net foreign trade) of approximately 18.02 BBF represented lumber consumption in the US in excess of that produced domestically. Hence, net foreign trade represented about 34.3 percent of total domestic lumber consumption in 2007.

Canada has been the leading exporter of softwood lumber to the US for many decades. Due to market development motivated by population and economic growth in the US, Canadian exports to the US have increased from less than five BBF billion board feet in 1965 to more than 16.59 BBF in 2007. In 2007, slightly more than 88 percent of all softwood lumber imported to the US originated from Canada (Random Lengths Publications, Inc. 2008b), which clearly indicates that Canada's softwood lumber producers represent an important element in meeting the demand for softwood lumber by US consumers. It is projected by that Canadian produced softwood lumber will represent roughly approximately one-third of US softwood lumber demand over the next fifty years, but imports from other countries (e.g., eastern Russia and Nordic countries) will increase to five percent of US softwood lumber consumption over the same time horizon (Haynes et al. 2000).

Both Canada and the US enjoy the benefits of the world's largest bilateral trading relationship. However, US-Canada trade is plagued by frequent disputes within natural resource industries – the most important and persistent of these disputes is that concerning trade in softwood lumber. The softwood lumber trade dispute has proven to be the most important in terms of product volumes and values, complexity, procedures, politicization, and duration (Cashore 1998; Gagne 1999; Zhang 1997). The Director of the Center for Trade Policy Studies at the Cato Institute stated (CATO 2001):

...this is an enormous trade dispute. It is our biggest ongoing dispute with our biggest trade partner. In dollar terms, the amount of softwood lumber that we import from Canada is roughly equal to the amount of carbon steel that we import from the whole world. And we all know the kind of attention that steel imports get and are getting right now. The lumber issue is every bit as big. It is just that it is with one country rather than dozens.

The history of the softwood lumber dispute between Canada and the US, as well as issues related to this event, have received considerable attention among academics (e.g.,

Devadoss and Roman 2004; Myneni et al. 1994; van Kooten 2002; Yin and Baek 2004; Zhang and Laband 2005). In the present study, we focus on the most current dispute and, in particular, the assessment methods used to examine the subject softwood lumber species.

The Trade Dispute Process

The US International Trade Administration (USITA) is responsible for the enforcement of antidumping and countervailing duty laws. It is responsible for administering antidumping and countervailing duty investigations, and it has the authority to initiate trade investigations. In countervailing duty cases, the US Department of Commerce (USDOC) determines whether products under investigation are being unlawfully subsidized, and if so, calculates the margin of subsidization and appropriate duties. Present law authorizes the imposition of antidumping and countervailing duties if a domestic producer is materially injured or threatened with material injury from a foreign competitor producing a "like product." The USDOC is charged with determining whether such imports are dumped in the US at unfairly low prices. Furthermore, the USDOC's responsibilities include conducting administrative reviews of outstanding countervailing duty orders and ensuring that these orders are properly administered by customs officials.

The US International Trade Commission (USITC) is responsible for specifically defining the relevant domestic industry in a trade dispute and establishing the existence of actual or threatened material injury due to subsidized imports. In order to maintain the competitiveness of domestic markets, the product market definition, as appears in the concepts of "like products" and "domestic industry," include those products that are competitive with or substitutes for suspect imports. However, the USITC's decision-making procedure shows a divergence from the ideal theoretical scenario. The statutory language and administrative interpretation of the antidumping and countervailing duty laws are ambiguous and unpredictable (Steen 1987). The US Court of International Trade (USCIT) has the authority to review determinations of the USDOC and the USITC. Under Chapter 19

of NAFTA, binational panels are appointed to hear disputes arising out of countervailing duty determinations between the parties to the agreement.

The General Agreement on Tariffs and Trade (GATT) is a legal instrument primarily focused on products. GATT is compacted with a number of legal obligations that lead to difficulty in determining when two physical products have such a relationship to one another so as to induce legal consequences. The most frequently encountered international trade phrase that creates this issue is "like products." However, several other terms are utilized in the economic and trade literature, such as like commodity, like merchandise, like or directly competitive products, like or directly substituted products, directly competitive or substitutable products, and identical or similar goods (Choi 2003). Note that a definition of "like" or "directly competitive or substitutable" products has yet to be unambiguously defined.

Bronckers and McNelis (1999), Choi (2003), Emch (2005), Fauchald (2003), Goco (2006), Matheny (1998), Steen (1987), and Zedalis (1994) explore the concept of like products as it applies to international trade and trade disputes. Collectively, these studies attempt to define a more justifiable and predictable application of the conceptual systems through interpretation of the World Trade Organization (WTO) Agreement.

The Current Dispute: Subsidies and Substitutability

The current Canadian-US softwood lumber dispute (Softwood Lumber IV) comprises a number of technically complex and interrelated issues that have made it difficult for the two countries to reach an agreeable resolution. The most significant issue in the softwood lumber trade dispute involves Canada's system of stumpage fees, whereby companies pay a fee to a provincial or territorial government for the right to harvest and process wood on a specific piece of land. In general, the US position states that Canada's provincial and territorial governments subsidize forestry companies by artificially setting stumpage fees below market value, which purportedly gives Canada's softwood lumber exporters an

unfair pricing advantage over American softwood lumber suppliers who sell lumber at a price that reflects the true economic cost of harvesting timber. Furthermore, US producers argue that they have been harmed or threatened with material injury by unfair Canadian competition (Gorte and Grimmett 2001).

Another important dimension in the Canadian-US softwood lumber trade dispute, which is the focal point of discussion and analysis in the present research, concerns the substitutability among imported and domestically produced softwood lumber species. Namely, should the various Canadian and US softwood species of lumber be considered identical products? Given the "like product" standard, the USITC is responsible for defining the relevant domestic industry and the products of concern for investigation when initiating an international trade investigation (Choi 2003).

In commencing a trade investigation, the USITC must first define the specific "domestic like product" and the specific "industry" that will be subject to investigation. Section 771(4)(A) of the Tariff Act of 1930 provides the USITC legal guidance in defining the "domestic like product," stating that it is "a product which is like, or in the absence of like, most similar in characteristics and uses with, the article subject to an investigation..."¹ The US Congress has directed the USITC to look for "clear dividing lines among possible like products" and further stated (United States International Trade Commission 2002, p. 8):

...the requirement that a product be 'like' the imported article should not be interpreted in such a narrow fashion as to permit minor differences in physical characteristics or uses to lead to the conclusion that the product and article are not "like" each other....

In *Softwood Lumber IV*, the USITC was repeatedly requested by the respondents (i.e., Canada) to define the point where various differences in softwood lumber species and

¹ See, e.g., *NVC Corp. v. Department of Commerce*, 36 F. Supp.2d 380; 383 (Ct. Int'l Trade 1998); *Nippon Steel Corp. v. United States*. 19 CIT 450, 455 (1995)

groups of softwood lumber species were sufficient enough to be a “clear dividing line” that warranted treating particular species as separate products (United States International Trade Commission 2002, p. 8). In a rather ambiguous determination, the USITC (2002, p.8) declared that “there are not clear dividing lines between the numerous species that comprise the continuum of softwood lumber....”

Note that the USITC’s decisions regarding appropriate domestic like products is, in theory, a factual determination. The USITC applies the statutory standard of “like” or “most similar in characteristics and uses” using a case-by-case scenario, taking into consideration the particular facts of each case (United States International Trade Commission 2002). A meaningful comparison of “like product” definitions, however, requires specifying the criteria by which likeness is to be objectively measured. A combination of six factors has traditionally been used by the USITC to determine like product status: physical characteristics and uses; interchangeability; common manufacturing facilities, production processes and production employees; channels of distribution; customer and producer perceptions or preferences of the products; and price (Choi 2003; Steen 1987; United States International Trade Commission 2002; VanSickle et al. 2003).

In assessing the like product issue in Lumber IV, the USITC relied upon a cointegration analysis on the subject softwood lumber species/species groups. Simply defined, cointegration analysis comprises the analysis of common trends over time, such as the trends in prices of two or more products. Here, the general hypothesis of cointegration analysis was that different species/species groups of North American softwood lumber products (e.g., 2x4’s, 2x10s) are nearly perfect substitutes (i.e., have high elasticity of substitution). To illustrate, the hypothesis suggests that spruce-pine-fir (SPF), the main Canadian softwood lumber species imported by the US, and southern yellow pine (SYP), the largest single softwood lumber species group produced in the US, are directly substitutable in the market place (Mercurio et al. 2002; Nagubadi 2004).

Several US consumer groups and the Canadian lumber industry, in contrast, claimed that Canadian softwood lumber imports and softwood lumber produced in the US were not direct substitutes (American Consumers for Affordable Homes 2002). Canada initiated eight cases in the World Trade Organization (WTO) in connection with softwood lumber issues, disputing the determinations of the USITC and imposition of antidumping and countervailing duties. These appeals have involved challenges to US trade statutes, such as the USITC's and US Department of Commerce's (USDOC) interpretation of the "like product" concept. The USDOC determination of "like product" is based on Article 2.6 of the Anti-Dumping Agreement (ADA) of The General Agreement on Tariffs and Trade (GATT) of 1994 and on footnote 46 of the WTO Agreement on Subsidies and Countervailing Measures (ASCM) which state (Choi 2003; Mastel 1998; World Trade Organization 2007, p. 526):

Throughout this Agreement the term 'like product' ('produit similaire') shall be interpreted to mean a product which is identical, i.e. alike in all respects to the product under consideration, or in the absence of such a product, another product which, although not alike in all respects, has characteristics closely resembling those of the product under consideration.

Canada claimed that the determinations made and methodologies employed by the USDOC under GATT of 1994, including Article 2.6 of the ADA, violated the process for determining like product definition in an attempt to create an obligation on members regarding how to define the product under consideration. In particular, the investigation initiated by the USDOC failed to contain sufficient analytical evidence of "most similar in characteristics and uses" among species/species groups under investigation in order for products to be considered "like" under ADA and the WTO ASCM articles, which Canada believed to be in violation of Article 2.6 of ADA of GATT and footnote 46 of the WTO ASCM. Canada claimed that the US was inconsistent with provisions of WTO agreements in that the USDOC's initiation of the investigation was not based on an objective and meaningful examination and determination of the concept of "likeness." Canada argued that the initiation by the USDOC was made without a proper establishment of facts, was

based on an evaluation of facts that was neither unbiased nor objective, and did not rest on a permissible interpretation of the ADA. Accordingly, the like product determination by the USDOC, Canada claimed, could not be upheld in light of the applicable standard of review under Article 2.6 (World Trade Organization 2002):

Commerce defined 'the product under consideration' and the 'like product' as 'all softwood lumber' and conducted a single anti-dumping investigation. Commerce's broad definitions did not identify a cohesive group of products that share common characteristics for either the 'product under consideration' or the 'like product.' Consequently, Commerce did not meet the requirements of the Article 2.6.

For most purposes, meaningful comparisons of "like product" definitions require specifying the characteristics by which likeness is to be measured. The WTO Appellate Body found that the USDOC's approach to defining "like product" was not inconsistent with Article 2.6 (Macrory et al. 2005).² The USDOC had defined "the product under consideration" (i.e., softwood lumber products) using narrative description and general tariff classification (World Trade Organization 2003).

Canada claimed that the definition of like products would benefit from clarification to limit the scope of product types that could be considered as a single "like product." This would reduce instances where products are broadly grouped together and treated as the same product when they, in fact, compete in different end-use markets (World Trade Organization 2003). In its second written submission, Canada made the following statement (World Trade Organization 2004, p. 25):

A failure to define like products in accordance with the requirements of Article 2.6 must be corrected.

With respect to each Canadian claim to the WTO Review Panel, the US contended that Canada either failed to identify an obligation implicated by the USDOC's action, or, where it identified an obligation, it had failed to demonstrate how the USDOC's actions were

² United States-Final Dumping Determination on Softwood Lumber from Canada.

inconsistent with that obligation. The WTO Review Panel (WTO 2004, p. 107) responded to the arguments, stating that:

Canada has a different interpretation of Article 2.6. In effect, Canada considers that, rather than comparing the overall scope of the product under consideration with the overall scope of the like product, Article 2.6 requires that each individual item within the 'like product' must be 'like' each individual item within the 'product of consideration'. This in effect means that there must be 'likeness' within both the product under consideration and within the like product....While there might be room for discussion as to whether such an approach might be an appropriate one from a policy perspective, whether to require such an approach is a matter for the Members to address through negotiations.

The final WTO Review Panel decision was issued on April 13, 2004. It found that elements of the US anti-dumping determination regarding softwood lumber were inconsistent with US WTO obligations. The US appealed the decision and on August 11, 2004, whereupon the WTO Appellate Body released its findings, which largely upheld the WTO Review Panel's decision. However, the WTO Review Panel decision was a nonbinding. Thus, the US was not forced to change any trade analysis policies as they applied to the Canadian-US softwood lumber investigation.

Cointegration Analysis in Defining Like Products

The present study specifically focuses on the appropriateness of utilizing cointegration analysis as a tool in defining the "like products" between goods produced in two (or more) different countries. In particular, we focus on whether the use of cointegration analysis is an appropriate tool to determine the substitutability of Canadian and US softwood lumber produced from various North American species/species groups.

Perez-Garcia and Manzin offer greater detail on the cointegration analysis of softwood lumber prices by species using long-run and short-run equations, which are estimated using advanced regression techniques known as multivariate cointegration and vector error correction methods (Mercurio et al. 2002). Their results expand on the earlier analysis of

the Law of One Price (LOP); namely, that a single price among products is observed for integrated markets. They do this by employing cointegration techniques that can more precisely test the relationship between price series as compared to simple correlation analysis. Their findings are consistent with similar analyses by Jung and Doroodian (1994), Murray and Wear (1998), and Uri and Boyd (1990), which suggest strong support for the LOP in softwood lumber markets. Moreover, they conclude that similar lumber products produced from different species are nearly perfect substitutes, given the fact that price movements of different species of lumber are highly correlated or nearly perfectly correlated (Mercurio et al. 2002).

Study Hypothesis

Various studies of Canada-US softwood lumber trade have made generalized conclusions that there appears to be evidence for different species of similar softwood products to be considered nearly perfect substitutes (Aguilar-Roman et al. 2006; Lewandrowski et al. 1994; Mogus et al. 2006; Nagubadi et al. 2004). These conclusions are based on the simple premise that if the price movements of different species of similar softwood lumber products are highly correlated, then these products must be substitutes. In the latest softwood lumber dispute (i.e., Softwood Lumber IV), the US petitioners went so far as state that the strong correlations between various species of softwood lumber (e.g., western red cedar and SPF) indicated that "different species of similar lumber products are nearly perfect substitutes" (Mercurio et al. 2002, p. 27). We propose a different hypothesis; namely, the high correlation of price movements of different species of similar softwood lumber products could be caused by common demand-side and/or supply-side market factors.

In this study, we employ the identical cointegration model that was utilized by the US petitioners in Softwood Lumber IV (Mercurio et al. 2002). We test our hypothesis by including additional products into the model whose derived demand, in theory, should be affected by similar factors that also affect the demand of different species of similar

softwood lumber products. Specifically, we focus on construction materials whose demand is highly tied to new residential construction activity. In the case of softwood lumber, it is estimated that nearly two-thirds of all softwood lumber makes its way into the residential construction market, albeit in different end-uses such as floor, roof, and wall framing applications (Shook et al. 2008).

In the next section, we provide an overview of the cointegration method used by US petitioners in *Softwood Lumber IV*, which, as aforesaid, is identical to the method used in this study. The analysis in this study provides statistical evidence supporting the hypothesis that softwood lumber prices are nonstationary time series. Modeling softwood lumber data without taking into account possible nonstationarity in the data could lead researchers to miss important features and properties of the data, which could lead to the estimation that can falsely represent the existence of a meaningful economic relationship.

Cointegration analysis provides an effective method to resolve the issues associated with nonstationary data without the loss of information associated with other forms of restoring stationarity to nonstationary data. We follow this with a brief discussion of the additional construction products and housing starts data that we added to the analysis. After discussing the results of our study, we provide some explanations as to why price parallelism may exist between different species of similar softwood lumber products, implications of our research, and suggested future research streams that would allow for a better understanding of the substitutability between different species of similar softwood lumber products.

METHODOLOGY

Data

Price data used in this study were obtained from *Random Lengths Yearbook* and consisted of monthly data spanning from January 1995 through October 2001 (Random Lengths Publications, Inc. 2001). Monthly series were used because they are sufficient to capture short-run movements over time without adding unnecessary complexity to the analysis. We incorporated the same eight 2x4-8' precision end trimmed (PET) softwood lumber species into our analysis that were evaluated by the US petitioners in their cointegration analysis in *Softwood Lumber IV* (Mercurio et al. 2002). In particular, the eight price series include kiln-dried Douglas-fir, random length 2x4-8' PET, stud grade; kiln-dried fir and larch, random length 2x4-8' PET, stud grade; kiln-dried hem-fir (Coast), random length 2x4-8' PET, stud grade; kiln-dried hem-fir (Inland), random length 2x4-8' PET, stud grade; kiln-dried southern pine (West), random length 2x4-8' PET, stud grade; kiln-dried spruce-lodgepole pine, random length 2x4-8' PET, stud grade; and SPF (West), random length 2x4-8' PET, stud grade. All prices are reported in US nominal dollar terms.

Our data includes the same time period as that used by Perez-Garcia and Manzin (Mercurio et al. 2002). Four additional wood-based panel products were also included in our study; these included 1/2-inch western plywood (4-ply CD exterior grade); 15/32-inch southern plywood (4-ply CD exterior, West price); 7/16-inch oriented strand board (Mid-Atlantic PALB); and 3/4-inch medium density fireboard (West PALO). Nominal price data for the four wood-based panels was obtained from *Random Lengths Yearbook* (Random Lengths Publications, Inc. 2001). Finally, we incorporated US single-family housing starts into our analysis, which was obtained from the US Census Bureau (United States Census Bureau 2008).

Theory of Cointegration Analysis

In this study, cointegration analysis is used to identify the relationship in prices among different species of similar softwood lumber products from North America. In addition, we estimate the short-run adjustments between softwood lumber price series using a vector error correction model (VECM). The underlying theory of the analysis, as advocated by the US petitioners in Softwood Lumber IV, states that cointegration results test if different species of similar lumber products have high substitution elasticity (i.e., like products).

There are several methods available for conducting the cointegration test. The most widely used methods include the residual-based Engle-Granger test, the maximum likelihood-based Johansen test, and the Johansen-Juselius test (Engle and Granger 1987; Johansen 1991; Johansen and Juselius 1990). According to cointegration theory, a $(N \times 1)$ vector time series, x_t , is said to be cointegrated if each of the elements of x_t is $I(1)$ individually (i.e., non-stationary with a unit root), but that some linear combination of the series, $a'x_t$, is stationary, or $I(0)$, for some nonzero $(N \times 1)$ vector, a (Engle and Granger 1987). Consequently, a test of the null hypothesis that $z_t = a'x_t$ is $I(1)$ is equivalent to a test of the null hypothesis that x_t is not cointegrated for a specific value a . In the context of the present study, cointegration implies that while the price series of various softwood lumber species, x_t , may behave like random walks, over the long run they will tend to drift in a similar manner, causing a linear combination of them, $a'x_t$, to reduce to a stationary process.

The Granger Representation Theorem demonstrates that error correction models can be estimated based on the estimated cointegration vector \hat{a} . When there are cointegration relations, VECMs provide a convenient representation of the vector time series, combining a dynamic short-run process and a long-run equilibrium (Song 2006).

Granger cointegration estimation typically begins with an estimate of \hat{a} by ordinary least squares regression (OLS). This is followed by the calculation of values for z and an estimated VECM (Engle and Granger 1987). Alternatively, the Johansen multivariate cointegration test is based on estimating vector autoregressive (VAR) models and involves a maximum likelihood estimation (MLE) method of identifying cointegration relationships (Johansen 1988, 1995; Johansen and Juselius 1990, 1992). A VAR model is estimated to capture the dynamic properties of the time series and test for cointegration. The existence of cointegration is used to identify a possible long-run relationship and examine its feedback into the two price series. The estimates and inference of the MLE for a VECM is believed to be more efficient than Granger's two-step estimation (Song 2006). The Johansen cointegration test, however, is preceded by a test of nonstationarity for the individual variables in the model to determine the order of integration of each variable.

Testing for Stationarity (Unit Roots)

Note that cointegration estimation assumes that individual price series are not stationary. Hence, a unit root test must first be performed prior to a cointegration estimation to determine if a price series is stationary or nonstationary. If a price series is stationary, then it should be excluded from the cointegration estimation (Hamilton 1994). There are various approaches to testing the null hypothesis that z_t is $I(1)$. In this study, we use two common unit root test methods; namely, the Dickey-Fuller unit root test (Dickey and Fuller 1979) and the Johansen test (Johansen 1995). The Johansen test is often thought to be superior unit-root test method since the Dickey-Fuller unit root test cannot resolve simultaneity biases caused by the use of more than one endogenous variable at the same time (Hamilton 1994; Jung and Dorodian 1994). However, the Dickey-Fuller test is more flexible in its ability to accommodate specifications associated with different data series.

Given the precondition for conducting a Johansen's multivariate cointegration test and estimating VECMs is that all the variables must be nonstationary, we first test the unit root hypothesis, which can be expressed as random walk:

$$X_t = \alpha + \rho X_{t-1} + \varepsilon_t \quad \text{Equation 1}$$

where α and ρ are parameters, X_{t-1} is the first lag of variable X_t , and ε_t is the residual. X is a stationary series if $-1 < \rho < 1$. If $\rho = 1$, X is a nonstationary series with drift α . The test for a unit root is constructed using the Dickey-Fuller unit root test. The null hypothesis of the Dickey-Fuller test is $H_0 : \rho = 1$; the one-sided alternative is $H_1 : |\rho| < 1$. The t-statistic of the OLS estimate for ρ has a limit distribution derived by Dickey and Fuller. The test is carried out by estimating an equation with x_{t-1} subtracted from both sides of the equation.

$$\Delta x_t = \alpha + (\rho - 1)x_{t-1} + \varepsilon_t \quad \text{Equation 2}$$

The Dickey-Fuller statistic is the ratio of $\hat{\rho} - 1$ to its standard error. The test is conducted under the null hypothesis of a unit root. If the calculated ratio is significantly different from zero, using the critical values calculated by Dickey and Fuller, then the null hypothesis is rejected.

To verify that the first-differenced price series are in fact stationary, the test methods for the generalized model (i.e., augmented Dickey-Fuller (ADF) unit root tests) were employed in this research. The ADF test is based on following regression:

$$\Delta X_t = \alpha + (\rho - 1)X_{t-1} + \sum_{i=1}^n \delta_i \Delta X_{t-i} + \varepsilon_t \quad \text{Equation 3}$$

where Δ is the first-difference operator and ε_t is a stationary error term. The null hypothesis is the same as that for the DF test. Limit distributions of the estimated parameters are similar to that for the DF test. The number of lags to include in the equation is determined using the Akaike information criterion (AIC).

Johansen Cointegration Test

The possibility of interpreting cointegration vectors as economic long-run relations largely explains why the vector autoregressive model has become used pervasively in the empirical analysis of economic data.

A multivariate cointegration analysis is performed on a set of stationary time series or prices, all of which have the same order of integration, typically first-order or $I(1)$. A set of such time series of prices can be described by a VAR model. For the Johansen cointegration test, consider a p -dimensional finite-order VAR model:

$$X_t = \alpha + A_1 X_{t-1} + \dots + A_k X_{t-k} + \Phi D_t + \varepsilon_t, \quad t = 1, \dots, T, \quad \text{Equation 4}$$

where X_t is a vector of p -empirical variables, α is a vector of constant terms, D_t is a d -vector of deterministic variables such as seasonal dummies, A_1, \dots, A_k and Φ are matrices of coefficients to be estimated, k is the lag length, and ε_t is the vector of error terms assumed to be $NID(0, \Omega)$.

Engle-Granger Two-Step Approach

An Engle-Granger's two-step process is one method occasionally used to estimate cointegrating vectors and consequently error correction models (Engle and Granger 1987). Where integrated series move together and their linear combination is stationary, the series are cointegrated and the confusion of spurious regressions is absent. Cointegration

implies the existence of a meaningful long-run equilibrium (Granger 1988). To estimate a long-run elasticity between Y_t and X_t we use the following regression:

$$Y_{it} = \beta_0 + \beta_1 X_{jt} + \varepsilon_t \quad \text{Equation 5}$$

where Y_{it} and X_{jt} are the nonstationary lumber price series. The first step of the cointegration approach is to estimate Equation 5 by the OLS. This estimation results in residuals ε_t . The next step of the cointegration test is to use the residual error from the cointegrating regression to test (using ADF statistics) whether or not ε is stationary. The ADF test on the residuals takes the following error correction form:

$$\Delta \hat{\varepsilon}_t = \beta \hat{\varepsilon}_{t-1} + \sum_{i=1}^K \Delta \hat{\varepsilon}_{t-i} + u_t \quad \text{Equation 6}$$

Variables Y and X might individually be nonstationary but if the estimate of their residual error is stationary (i.e., the residual does not contain a stochastic trend), the variables are said to cointegrate. It implies that Y and X form a long-run relationship and the regression is not spurious. If Y_t and X_t are cointegrated, then the OLS estimator of the coefficient in the cointegrating regression in Equation 5 is consistent. However, even if the variables imply cointegration, the OLS estimate of the cointegrating vector will contain a small sample bias (i.e., biased by endogeneity among the variables) and have non-normal distribution with a non-zero mean (Stock 1987; Stock and Watson 2007). In order to avoid misinterpreting spurious regression results, econometricians have developed a number of other estimators of the cointegrating coefficient, such as the dynamic ordinary least squares (DLOS) estimator (Stock and Watson 1993). The DOLS estimator of a homogeneous cointegration vector is based on a modified version of a basic ordinary least squares estimation (Equation 5) techniques by including both leads and lags of first difference of all explanatory variables:

$$Y_{it} = \beta_0 + \beta_1 X_{jt} + \sum_{k=-p}^p \beta_k \Delta X_{jt-k} + u_t \quad \text{Equation 7}$$

where Y_{it} and X_{jt} are the lumber price variables and $\sum_{k=-p}^p \beta_k \Delta X_{jt-k}$ (k ranges from -p to +p, or pth order) are leads and lags of variable X_{jt} .

The long-run residual terms from Equation 7, u_t , represent the error terms from the long-run equilibrium. These errors will be used in second step of the cointegration procedure, which represents the short-run dynamics of the model.

Vector Error Correction Model

This VECM can be expressed as follows:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \varepsilon_t, \quad t = 1, \dots, T, \quad \text{Equation 8}$$

$$\text{with } \Pi = \sum_{i=1}^p A_i - I, \quad \Gamma_i = -\sum_{j=i+1}^p A_j \quad \text{Equation 9}$$

There are several useful aspects regarding the VECM functional form, including the ability to conduct tests regarding the cointegration status of the set of time series, as well as the ability to separate parts of the model that govern long-run and short-run behavior. The cointegration tests involve the matrix Π that is a coefficient matrix for the first-differenced term in the VECM model. Π is the only term in the VECM that is not $I(0)$. The tests for cointegration are tests for the rank or the number of linearly independent rows or columns of Π .

If the rank r of the Π matrix indicates cointegration, then to better understand the cointegrating vector, the Π matrix can be decomposed into the product of two vectors α and β . In this decomposition the matrix β consists of the cointegration relationships, with as many distinct cointegration vectors as the rank r of Π , while the matrix α consists of the adjustments factors that multiply the cointegration relationships. Granger's representation theorem asserts that if the coefficient matrix Π has reduced rank $r < n$, then there exist $n \times r$ matrices α and β with rank r such that $\Pi = \alpha\beta'$ and $\beta'x_t$ is stationary (Engle and Granger 1987). For n endogenous non-stationary variables, there can be from zero to $n - 1$ linearly independent, cointegrating relations.

The estimation procedure involves three distinct steps. First, one conducts an analysis of individual time series to estimate lag-length, determine the need for any deterministic terms, and to test for nonstationarity. Second, to be consistent with Perez-Garcia and Manzin's cointegration estimation process, Engle-Granger two-step procedure is performed on all series that are of the same order of nonstationarity (typically $I(1)$), to estimate the number of cointegrating relationships (Mercurio et al. 2002). The final step proceeds if cointegrating relationships are found in the second step, and it involves characterizing the cointegrating relationships, adjustment factors, and the short-term part of the VECM model. A residual analysis is also conducted to verify that the model assumptions regarding the errors hold; namely, that they are normally distributed, homoscedastic, and exhibit no autocorrelation.

RESULTS AND DISCUSSION

A prerequisite to utilizing cointegration analysis includes testing the time series for nonstationary unit root processes. Econometric analysis of the classical linear regression model depends heavily on the assumption that observed data result from stationary data generation processes. A time series ($X_t, t(\text{time}) = 0, \pm 1, \pm 2, \dots$) is said to be stationary if it has statistical properties similar to those of the time-shifted series ($X_{t+k}, t = 0, \pm 1, \pm 2, \dots$) for each integer k . In practice, however, many economic time series are non-stationary and exhibit a trend, and often the non-stationary component (i.e., trend) is of most interest (Nelson and Plosser 1982; Ragavan and Fernandez 2006). The existence of a unit root was first tested using the ADF test (Dickey and Fuller 1979). SAS provides the formal Dickey and Fuller test method, using the ARIMA procedure, to test for unit root non-stationarity. Since AR terms were present with large autoregressive terms, the ADF test for a unit root was used (Hamilton 1994). The lag length ($k = 5$) with a constant mean was chosen for each ADF test, since this model generally gave a good fit to the data for each series.

Table 1 presents the results of the ADF unit root tests for each of the lumber price series under study. The test results indicate that there was a unit root non-stationarity in each series. The same results generally occurred with different numbers of lags and either a trend term or a zero mean. The null hypothesis of a unit root test, therefore, was rejected for the first differenced series both at the 1 percent level and the 5 percent level, leading to the conclusion that all the lumber prices are integrated of order one (i.e., stationary in first differences). Having confirmed that each series is integrated of order (1) allows us to proceed to the cointegration tests.

Table 1. Augmented Dickey-Fuller unit root tests results for various North American species of softwood lumber, wood-based panels, and US housing starts data series.

Lumber Price Series	ADF Test Statistic (Tau)^a	p-value	Unit Root; Order of Integration
Douglas-fir	-3.28	0.0194	Unit Root; <i>I</i> (1)
Fir & Larch	-3.34	0.0164	Unit Root; <i>I</i> (1)
Hem-Fir (Coast)	-2.42	0.1382	Unit Root; <i>I</i> (1)
Hem-Fir (Inland)	-3.16	0.0263	Unit Root; <i>I</i> (1)
Southern Pine (West)	-3.37	0.0151	Unit Root; <i>I</i> (1)
Spruce-Lodgepole Pine	-2.62	0.0938	Unit Root; <i>I</i> (1)
Spruce-Pine-Fir (West)	-2.75	0.0704	Unit Root; <i>I</i> (1)
Western Plywood	-3.39	0.0142	Unit Root; <i>I</i> (1)
Southern Plywood (West)	-2.88	0.0517	Unit Root; <i>I</i> (1)
Oriented Strand Board	-2.70	0.0791	Unit Root; <i>I</i> (1)
Medium Density Fiberboard	-3.20	0.0247	Unit Root; <i>I</i> (1)
Housing Starts	-3.66	0.0160	Unit Root; <i>I</i> (1)

^a The single mean model is used because there is an intercept term in the time series model.

The results of the Engle and Granger two-step procedure for cointegration are presented in Table 2. The results indicate if a non-stationary variable are cointegrated establishing a long-run relationship. The ADF test is performed on the residuals from OLS estimation for Canadian and US product pairs. As the table shows, we reject the hypothesis for the presence of unit root in the first step residual series in all of the cases. All regressions reported are cointegrated at the 5 percent and in most cases at the 1 percent significance level. This suggests that the estimated equations reflect stable long-run relationships.

To examine long- and short-run relationships we employ the same equation as that used by Perez-Garcia and Manzin (Mercurio et al. 2002). The long-run cointegrating relationship is based on the Equation 7 (all variables are in log form except for the time trend):

$$Y_{it} = \beta_0 + \beta_1 X_{jt} + \sum_{k=-p}^p \beta_t \Delta X_{jt-k} + \beta_2 T + \eta_t \quad \text{Equation 11}$$

where Y_{it} and X_{jt} are the price of lumber by species I and j, T is a time trend, and η_t is the long-run error terms, which later is noted as ECM_L . The ECM_L will be used as a variable in the short-run relationship.

The long-run estimations are presented in Table 3. Lags and leads of the first differences of the right hand side variables are added to the equation to correct the possible correlation of the error terms. The strong LOP is a test of $\beta = 1$ and the weak LOP is a test of $\beta = 0$. Even though there is a cointegrating relationship between the two price series, it does not imply that the strong LOP holds. The table indicates whether the strong LOP holds. The adjusted R-squared values are given within parentheses.

The short-run cointegrating relationship is based on an ECM with the error terms from the long-run relationship:

$$\Delta Y_{it} = \beta_0 + \sum_{k=0}^p \beta_t \Delta X_{jt-k} + \beta_1 T + \beta_2 ECM_{L-1} + \eta_t \quad \text{Equation 12}$$

where ΔY_{it} and ΔX_{jt} are the first differences of price I, and j; T is a time trend, ECM_L is the error terms from the long-run estimation, and η_t is the short-run error terms. The regression produces the short-run estimation of price relationships between integrated

markets. The coefficient of the ECM_{L-1} term represents the short-run adjustment time, which links the long- and short-run estimations.

The short-run cointegrating relationships are presented in Table 4. The error correction term is derived from the long-run model presented in Table 3.

The long- and short-run elasticity between pairs are presented in Table 5, as well as the adjustment time required to reach the long-term equilibrium.

Table 2. Results of Engle-Granger cointegration procedure for various North American species of softwood lumber, wood-based panel products, and US housing starts data series.

Price Series: Dependent – Independent Variable	ADF Test		Cointegrated Relationship
	Statistic (Tau) ^a [lags]	p-value	
SPF-W [base] – Douglas-fir	-3.52 [1]	0.0006	Yes
Douglas-fir– SPF-W [base]	-4.49 [1]	< 0.0001	Yes
SPF-W [base] – Fir & Larch	-3.56 [1]	0.0005	Yes
Fir & Larch– SPF-W [base]	-4.34 [1]	< 0.0001	Yes
SPF-W [base] – Hem-Fir (Coast)	-4.34 [0]	< 0.0001	Yes
Hem-Fir (Coast) – SPF-W [base]	-4.24 [1]	< 0.0001	Yes
SPF-W [base] – Hem-Fir (Inland)	-3.39 [0]	0.0009	Yes
Hem-Fir (Inland) – SPF-W [base]	-4.63 [1]	< 0.0001	Yes
SPF-W [base] – S. Pine (West)	-4.72 [0]	< 0.0001	Yes
S. Pine (West) – SPF-W [base]	-4.50 [1]	< 0.0001	Yes
SPF-W [base] –Spruce-Lodgepole Pine	-5.95 [0]	< 0.0001	Yes
Spruce-Lodgepole Pine – SPF-W [base]	-5.54 [0]	< 0.0001	Yes
SPF-W [base] –W. Plywood	-2.95 [1]	0.0037	Yes
W. Plywood - SPF-W [base]	-3.87 [1]	0.0002	Yes
SPF-W [base] – S. Plywood	-2.62 [1]	0.0093	Yes
S. Plywood – SPF-W [base]	-2.60 [1]	0.0097	Yes
SPF-W [base] – OSB	-3.31 [1]	0.0012	Yes
OSB – SPF-W [base]	-2.32 [1]	0.0204	Yes
SPF-W [base] –MDF	-3.00 [1]	0.0033	Yes
MDF – SPF-W [base]	-2.81 [1]	0.0056	Yes
SPF-W [base] –Housing Starts	-2.84 [1]	0.0050	Yes
Housing Starts – SPF-W [base]	-5.23 [1]	< 0.0001	Yes

^a The zero mean model is used because it is assumed that the series mean is 0 whether or not there are unit roots.

Table 3. Estimated long-run relationship between pairs of various North American species of softwood lumber, wood-based panel products, and US housing starts data series.

Dependent – Independent Price Variables	Coefficient Estimate of Independent Price Variable (R^2)	Law of One Price
SPF-W [base] – Douglas-fir	1.2777 (0.64)	Holds
Douglas-fir – SPF-W [base]	0.5300 (0.62)	Holds
SPF-W [base] – Fir & Larch	1.2778 (0.67)	Holds
Fir & Larch – SPF-W [base]	0.5425 (0.66)	Holds
SPF-W [base] – Hem-Fir (Coast)	1.0638 (0.95)	Holds
Hem-Fir (Coast) – SPF-W [base]	0.8874 (0.96)	Holds
SPF-W [base] – Hem-Fir (Inland)	1.2042 (0.83)	Holds
Hem-Fir (Inland) – SPF-W [base]	0.6682 (0.84)	Holds
SPF-W [base] – S. Pine (West)	0.7078 (0.76)	Holds
S. Pine (West) – SPF-W [base]	1.1547 (0.79)	Holds
SPF-W [base] – Spruce-Lodgepole Pine	0.9785 (0.97)	Holds
Spruce-Lodgepole Pine – SPF-W [base]	1.0025 (0.98)	Holds
SPF-W [base] – W. Plywood	0.3894 (0.18)	Holds
W. Plywood – SPF-W [base]	0.3540 (0.19)	Holds
SPF-W [base] – S. Plywood	0.2688 (0.12)	Holds
S. Plywood – SPF-W [base]	0.2297 (0.09)	Holds
SPF-W [base] – OSB	0.1006 (0.21)	Holds
OSB – SPF-W [base]	0.3918 (0.04)	Holds
SPF-W [base] – MDF	0.2544 (0.19)	Holds
MDF – SPF-W [base]	0.0925 (-0.02)	Holds
SPF-W [base] – Housing Starts	0.4432 (0.13)	Holds
Housing Starts – SPF-W [base]	0.4678 (0.15)	Holds

Table 4. Estimated short-run relationship between pairs of various North American species of softwood lumber, wood-based panels, and US housing starts data series.

Dependent – Independent Price Variables	Coefficient Estimate of Independent Price Variable	Coefficient of the Error Correction Term	R²
SPF-W [base] – Douglas-fir	1.0481	-0.2613	0.67
Douglas-fir – SPF-W [base]	0.5980	-0.3660	0.69
SPF-W [base] – Fir & Larch	1.0120	-0.2699	0.73
Fir & Larch – SPF-W [base]	0.6804	-0.3448	0.74
SPF-W [base] – Hem-Fir (Coast)	0.9702	-0.2630	0.90
Hem-Fir (Coast) – SPF-W [base]	0.9266	-0.2986	0.91
SPF-W [base] – Hem-Fir (Inland)	1.0770	-0.2965	0.80
Hem-Fir (Inland) – SPF-W [base]	0.7172	-0.3754	0.82
SPF-W [base] – S. Pine (West)	0.5585	-0.3852	0.46
S. Pine (West) – SPF-W [base]	0.7419	-0.4361	0.59
SPF-W [base] – Spruce-Lodgepole Pine	0.9909	-0.2153	0.91
Spruce-Lodgepole Pine – SPF-W [base]	0.9181	-0.2091	0.91
SPF-W [base] – W. Plywood	0.6596	-0.1806	0.45
W. Plywood – SPF-W [base]	0.5520	-0.2827	0.48
SPF-W [base] – S. Plywood	0.5814	-0.1589	0.43
S. Plywood – SPF-W [base]	0.6439	-0.1392	0.39
SPF-W [base] – OSB	0.3028	-0.2293	0.48
OSB – SPF-W [base]	1.0575	-0.1286	0.37
SPF-W [base] – MDF	1.1192	-0.2786	0.16
MDF – SPF-W [base]	0.0397	-0.1388	0.22
SPF-W [base] – HS	0.0569	-0.1821	0.12
HS – SPF-W [base]	-0.0072	-0.4292	0.32

Table 5. Estimated long-run elasticity, short-run elasticity, and adjustment time between pairs of various North American species of softwood lumber, wood-based panels, and housing starts data series.

Dependent – Independent Price Variables	Long-run Elasticity	Short-run Elasticity	Adjustment Time (months)
SPF-W [base] – Douglas-fir	1.2777	1.0481	3.8
Douglas-fir – SPF-W [base]	0.5300	0.5980	2.7
SPF-W [base] – Fir & Larch	1.2778	1.0120	3.7
Fir & Larch – SPF-W [base]	0.5425	0.6804	2.9
SPF-W [base] – Hem-Fir (Coast)	1.0638	0.9702	3.8
Hem-Fir (Coast) – SPF-W [base]	0.8874	0.9266	3.3
SPF-W [base] – Hem-Fir (Inland)	1.2042	1.0770	3.4
Hem-Fir (Inland) – SPF-W [base]	0.6682	0.7172	2.7
SPF-W [base] – S. Pine (West)	0.7078	0.5585	2.6
S. Pine (West) – SPF-W [base]	1.1547	0.7419	2.3
SPF-W [base] – Spruce-Lodgepole Pine	0.9785	0.9909	4.6
Spruce-Lodgepole Pine – SPF-W [base]	1.0025	0.9181	4.8
SPF-W [base] – W. Plywood	0.3894	0.6596	5.5
W. Plywood – SPF-W [base]	0.3540	0.5520	3.4
SPF-W [base] – S. Plywood	0.2688	0.5814	6.3
S. Plywood – SPF-W [base]	0.2297	0.6439	7.2
SPF-W [base] – OSB	0.1006	0.3028	4.4
OSB – SPF-W [base]	0.3918	1.0575	7.8
SPF-W [base] – MDF	0.2544	1.1192	3.6
MDF – SPF-W [base]	0.0925	0.0397	7.2
SPF-W [base] – Housing Starts	0.4432	0.0569	5.5
Housing Starts – SPF-W [base]	0.4678	-0.0072	2.3

CONCLUSIONS

In this study, we examine US petitioner's cointegration methodology that was used in the last round of the Canadian-US softwood lumber trade dispute to explain why all species of North American softwood lumber were considered to be perfect substitutes for one another. Specifically, in the US petitioner's analysis, the authors stated that strong statistical correlations between various species of softwood lumber (e.g., western red cedar and SPF) indicated that "different species of similar lumber products are nearly perfect substitutes" (Mercurio et al. 2002, p. 27). The petitioner's analysis, however, is deficient in that it does not account for factors that may lead to price parallelism among various North American softwood lumber species.

The present study expands upon the petitioner's cointegration analysis by including four additional wood-based products (medium density fiberboard, oriented strandboard, southern plywood, western plywood) with the softwood lumber species examined in the original analysis. The fundamental hypothesis in our study is that shared demand factors (i.e., derived demand) could lead a wide variety of softwood products to exhibit statistically significant correlations among their price series, regardless of their product form. If cointegration were found to exist between a panel product(s) and a species of softwood lumber, for instance, then we could be somewhat certain that alternative reasons could be provided to explain why prices for wood-based products, in general, would follow similar trends over time (i.e., they are not direct substitutes). Finally, we incorporated US single-family housing starts into the cointegration procedure. In theory, the demand for new homes, namely housing starts, should be cointegrated with the prices of North American softwood lumber. This would provide compelling evidence of the derived demand relationship between product and end-use market.

The present study used the identical methodology as that employed by US petitioners with one difference (Mercurio et al. 2002). Unlike the petitioner's study, we use the Engle-

Granger two-step cointegration test to examine if unique cointegrating relationship existed among the North American softwood lumber prices (Engle and Granger 1987). Our expanded methodological approach allowed us to test for a long-run relationship among variables that are individually nonstationary. Our tests for nonstationarity using the ADF unit root test, as well as our cointegration results, essentially confirm petitioner's results reported in the latest Canadian-US softwood lumber trade dispute (Mercurio et al. 2002); namely, there is a long-term cointegrating relationship among North American softwood lumber species' prices.

When the petitioner's cointegration method is expanded to include other types of wood-based products and housing starts (i.e., demand-side factor), our ADF unit root test and cointegration results allow us to conclude that a long-run equilibrium relationship exists between North American softwood lumber species and softwood panel products, as well as US housing starts. Furthermore, our empirical results did not demonstrate any strong evidence to support petitioner's hypothesis of perfect substitutability between different North American species of softwood lumber. This finding is interesting since it contradicts theoretical expectations.

Wood-based panels are products of a significantly different form relative to softwood lumber. Yet, immense volumes of both wood-based panels and softwood lumber are used in the residential construction market. Given that the price movements of different wood-based panel products are highly correlated with North American softwood lumber species, we fail to conclude that North American softwood lumber species can be claimed as nearly perfect substitutes. Moreover, by including US housing starts into our analysis, we support our hypothesis that high correlation of price movements of different species of similar softwood lumber products is likely being caused by a common demand-side factors. In sum, we find that it is just as plausible that the cointegration in prices among North American softwood lumber species can be caused by common demand-side market factors, such as residential construction activity and building new homes.

Study Limitations and Suggest Future Work

As with any empirical study, several limitations exist in our study that affect both the methodological task and the inferences gained from the empirical results. It should be noted that the Engle-Granger two-step cointegration approach used in this study is not the most widely used test of cointegration. The procedure concentrates on a single equation, with one variable designated as the dependent variable, explained by other variables that are assumed to be weakly exogenous for the parameters of interest. The maximum likelihood-based Johansen test for cointegration and the Johansen-Juselius cointegration approach allow one to deal with models containing several endogenous variables (i.e., more than one relationship) and have a number of other advantages relative to the Engle-Granger approach (Johansen 1991; Johansen and Juselius 1990).

Two specific limitations exist in this study with regard to the estimation method. First, the method relies on a two-step estimator; the initial step generates the error series, while the second step uses the error series to estimate the regression. Thus, error introduced in initial step will be carried into the second step (i.e., error propagation). Second, the estimation of a long-run equilibrium regression requires that one variable is placed on the left-hand side, while all remaining variables are regressors. The large sample properties used may not be applicable to the sample sizes usually available for cointegration tests. It has been suggested that the Johansen approach be used to avoid these issues (Hamilton 1994).

Future research could incorporate the price series of other building materials that are strongly associated with residential construction activity (e.g., cement and concrete, drywall). For instance, empirical results showing that drywall prices are cointegrated with North American softwood lumber prices would provide strong evidence that derived demand can result in price parallelism of seemingly unrelated product categories and product forms.

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