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International Economics Department
The World Bank
August 1990
WPS 465

# How Integrated Are Tropical Timber Markets?

Panos Varangis



Do tropical timber price series — across species, products, and regions — move together, at least in the long run? Most do, tests show.

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This paper — a product of the International Commodity Markets Division, International Economics Department — is part of a larger effort in PRE to examine price formation in primary commodity markets. Copies of this paper are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Dawn Gustafson, room S7-044, extension 33714 (25 pages, including graphs and tables).

The tropical timber market is characterized by multiple species, multiple products, and regional patterns of production and trade. In such a market, finding a representative price is a difficult and perhaps an irrelevant task. So Varangis conducted tests to see whether prices from different species, products, and regions move together, at least in the long run. If they do, the use of a representative price may be appropriate. The analysis could also be seen as a test of whether the Asian and African/European markets are interdependent.

The following are the test results:

• All series, except that for teak, were found to be cointegrated. The results for teak may be explained on the grounds that the series was the only domestic price series; all other prices are internationally traded. Also, but not very likely, the relative shortness of the teak series may have reduced the tests' power.

• Tropical timber prices in the major geographical regions move together. There may be short-term deviations, but market forces pull these regional prices together in the long run.

• Given that prices move together, the long-run forecast for one has implications for the others.

• Log and sawnwood prices move together, which is to be expected since logs are the primary input for sawnwood.

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by
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## INTRODUCTION

1. The tropical timber market is characterized by a large number of species and also by numerous processed products. In 1945, only 19 species were widely known and traded, while today this number has climbed to about 150. While in the past most of the trade was in the form of logs, recently the share of processed tropical timber has increased considerably. Table 1 shows the evolution in trade volumes for selected tropical timber products.

Table 1: VOLUME OF TRADE IN TROPICAL TIMBER PRODUCTS

| | 1969-71 | 1979-81 | 1986-88 |
|---|---|---|---|
| | -----------'000 cubic meters------------- | | |
| Logs | 36,107 | 37,359 | 28,967 |
| Sawnwood | 4,394 | 8,958 | 9,963 |
| Plywood | 1,816 | 3,127 | 7,700 |
| Veneer sheets | 548 | 500 | 853 |

Source: IECCM and FAO.

2. Another characteristic of the tropical timber market is the geographical pattern of trade. There are two dominant markets for logs. Most of the logs produced and exported by South East Asian producing countries are imported by countries in the Far East, primarily Japan, Republic of Korea, Singapore, and Taiwan (China). Most of the logs exported from African countries are imported by Western European countries. There is cross-region trade but not at very significant levels. These geographical patterns in log trade have changed little over time. However, trade in the processed products has much less of a regional pattern.

3. In a market such as the tropical timber market, characterized by multiple species and products as well as regional trade patterns, finding a representative price is a difficult task and perhaps an irrelevant matter. Therefore, a question that arises in such a case is whether prices from different products, species and regions have a long-run stationary relationship. That is, in the short-run prices may well deviate, but in the long-run market forces may pull them together. The purpose of this paper is to test whether tropical timber prices move together in the long-run. The analvsis can also be taken as a test of whether the Asian and African/European markets are closely linked or whether they are two quite separate markets. Section I presents the methodology employed for testing whether a long-run stationary relationship exists between timber prices. The Phillips test for existence of a trend in the series and Perron's test for structural breaks are also described as these have been used as part of the testing procedures. Section II describes the data. Section III provides the test results and discussion.

## I. STATISTICAL TECHNIQUES

4. The technique for examining whether two time series have a stationary relationship over the long-run, i.e., move together, is based on the integration and cointegration test procedures. Tests for cointegration provide evidence of a stationary relationship between two series. However, before testing for cointegration, the two series should be tested to see if they have the same intertemporaral properties, i.e., they are integrated of the same order.

5. The dynamic property of a time series can be described by how often it needs to be differenced to achieve time-invariant linear properties and provide a stationary process. A series that has at least invariant mean and variance and whose autocorrelation has "short memory" is called I(0), denoting "integrated of order zero". A series which needs to be differenced n times to become I(0), i.e., become stationary, is said to be integrated of order n, denoted as I(n). A large number of economic variables need to be differenced once to become stationary which makes them I(1), i.e., they have a unit root.

6. There are substantial differences between I(0) and I(1) series. An I(0) series possesses the following characteristics: (i) its variance is finite; (ii) a shock has only a temporary effect; and (iii) the expected length of time between crossings of its mean is finite. For an I(1) series (i) its variance goes to infinity as t goes to infinity; (ii) a shock has a permanent effect; and (iii) the expected time between crossings of its mean is indefinite.

7. The simplest example of a non-stationary I(1) series is the random walk:

$$X_t = X_{t-1} + e_t \tag{1}$$

where $e_t$ is independent and normally distributed. In this case, assuming that $X_o = 0$

$$X_t = e_t + e_{t-1} + \dots + e_1 \tag{2}$$

From (2) it is easily observed that $X_t$ is the sum of past shocks, $e_t$, no matter how long ago they occurred. That is, shocks have a permanent effect on $X_t$ and thus the series has a "long memory". However, if we first difference (1) we obtain:

$$X_t - X_{t-1} = e_t \tag{3}$$

which is stationary.

The simplest example of a stationary I(0) series is white noise. That is, in (3) $e_t$ is independently distributed.

8. There are three test procedures to test the null hypothesis of the existence of a unit root in a series, i.e., test whether a series is I(1). These are (i) the Durbin-Watson test of Sargan and Bhagrava (CRDW); (ii) the Dickey-Fuller test (DF); and (iii) the Augmented Dickey-Fuller test (ADF).

All three test procedures test the null hypothesis $H_0 : X_t$ is I(1). The three test procedures employed are described below:

CRDW : $X_t = a + e_t$

$H_o : X_t$ is I(1) if DW is below a critical value (defined below)

DF: $\Delta e_t = a + \beta e_{t-1} + v_t$

$H_o : X_t$ is I(1) if $\beta$ is negative and its t-statistic is below a critical value (defined below). 1/

ADF : $\Delta e_t = a + \beta e_{t-1} + \sum_{i=1}^{n} \gamma_t \Delta e_{t-1} + v_t$

$H_o : X_t$ is I(1) if $\beta$ is negative and its t-statistic is below a critical value (defined below).

where $e_t$ are the residuals from the $X_t$ and are white noise and n in the ADF test is selected to be large enough to ensure the residuals $v_t$ are white noise. A statistically significant, negative coefficient $\beta$ signifies that changes in $X_t$ or $e_t$ can be reversed over time and that their levels are stable over the long term.

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1/ The test statistic is the t-statistic for Beta, but the Student's t-distribution is not appropriate.

9. The critical values for the three different tests at the 99%, 95% and 90% significance levels are presented below. The critical values for the DF and ADF test statistics were obtained through Monte Carlo simulations, based on 100 observations and with 10,000 replications, under the assumption that $\Delta e_t$ is identically and normally distributed.

Critical Values of Unit Root Tests

| Tests | Levels of Significance | | |
|---|---|---|---|
| | 90% | 95% | 99% |
| CRDW | 0.322 | 0.386 | 0.511 |
| DF | 3.03 | 3.37 | 4.07 |
| ADF | 2.84 | 3.17 | 3.77 |

Source: Engle and Granger (1987).

10. In the case of non-autocorrelation in the residuals, $\Delta e_t$, the ADF test is misspecified and less powerful than the DF test since it estimated parameters that are truly zero. In the case of autocorrelation, the DF is misspecified and less powerful than the ADF test. The CRDW test performs better overall in both the non-autocorrelated and autocorrelated cases according to the power calculations of Engle and Granger (1987). However, its critical values are sensitive to the particular parameters within the null hypothesis as well as to the sample size. In order to avoid misleading results from these tests all three tests are applied.

11. A problem in the identification of the unit root of a time series is the existence of a trend. A series can be misspecified to be I(1) while it is I(0) with a deterministic time trend. To illustrate by a simple example, a series can be identified as a random walk:

$$X_t = X_{t-1} + U_t \tag{4}$$

while its correct generating mechanism is

$$X_t = a + bt + e_t \tag{5}$$

in which case $X_t$ follows a deterministic trend about white noise. Durlauf and Phillips (1988) have suggested the following procedure (known as the Phillips test) in order to discriminate between models (4) and (5): estimate equation (5) by OLS and obtain the residuals $e_t$; then apply the DF and ADF tests as described previously. The DW statistic from equation (5) can also be used to perform the CRDW test. Alternatively, one can use the classical F test on a hybrid regression of the form:

$$X_t = a + bt + cX_{t-1} + U_t \tag{6}$$

The F-test is used to test hypotheses applied to the various regression coefficients. Acceptance of the hypothesis that b = 0 and c = 1 corresponds to the acceptance of the I(1) process, model (4), and the presence of a unit root in $X_t$. Conversely, acceptance of the hypothesis that c = 0 corresponds to the rejection of the presence of a unit root in $X_t$. It should be noted, however, that Nelson

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1/ See Perron (1989

## II. DATA DESCRIPTION

13. Long, consistent-quality time series on tropical timber prices are rare. The length of the series is of importance when performing integration and cointegration tests since the critical values for both are based on large samples; moreover, since cointegration is a test for long-term relationships, the number of observations in the sample is not as important as the time span that the observations cover. For example, a sample of 100 quarterly observations (4 times 25 years would be preferable to a sample consisting of 180 monthly observations (12 times 15 years).

14. The time series were chosen to cover several species and products in the different markets. While it was possible to find some long series for logs in the two markets, usable price series for sawnwood and plywood were found only for the Southeast Asian region and then only for one species for sawnwood and one type of plywood.

15. A brief description of each price series follows:

Logs

- Meranti (Malaysia). Best quality, dark red meranti from Sabah. This price is the sale price charged by importers in Japan. Data from 1956 to 1989.

- <u>Teak</u> (Thailand). Domestic wholesale price of teak logs. Data from 1965 to 1987.

- <u>Sapelli</u> (Cameroon). The Cameroonian FOB price for high quality sapelli logs. Data from 1956 to 1989.

- <u>Niagon</u> (Côte d'Ivoire). Standard quality niagon logs, FOB Abidjan. Data from 1956 to 1989.

- <u>Samba</u> (Côte d'Ivoire). Standard quality samba logs, FOB Abidjan. Data from 1956 to 1989.

<u>Sawnwood</u>

- <u>Sawnwood</u> (Malaysia). Dark red meranti, select and better quality of standard density, CIF French ports. Data from 1958 to 1989.

<u>Plywood</u>

- <u>Plywood</u>. Lauan plywood, 3-ply extra, 91cm X 182 cm X 6mm, spot wholesale price in the Tokyo market. Data from 1963 to 1989.

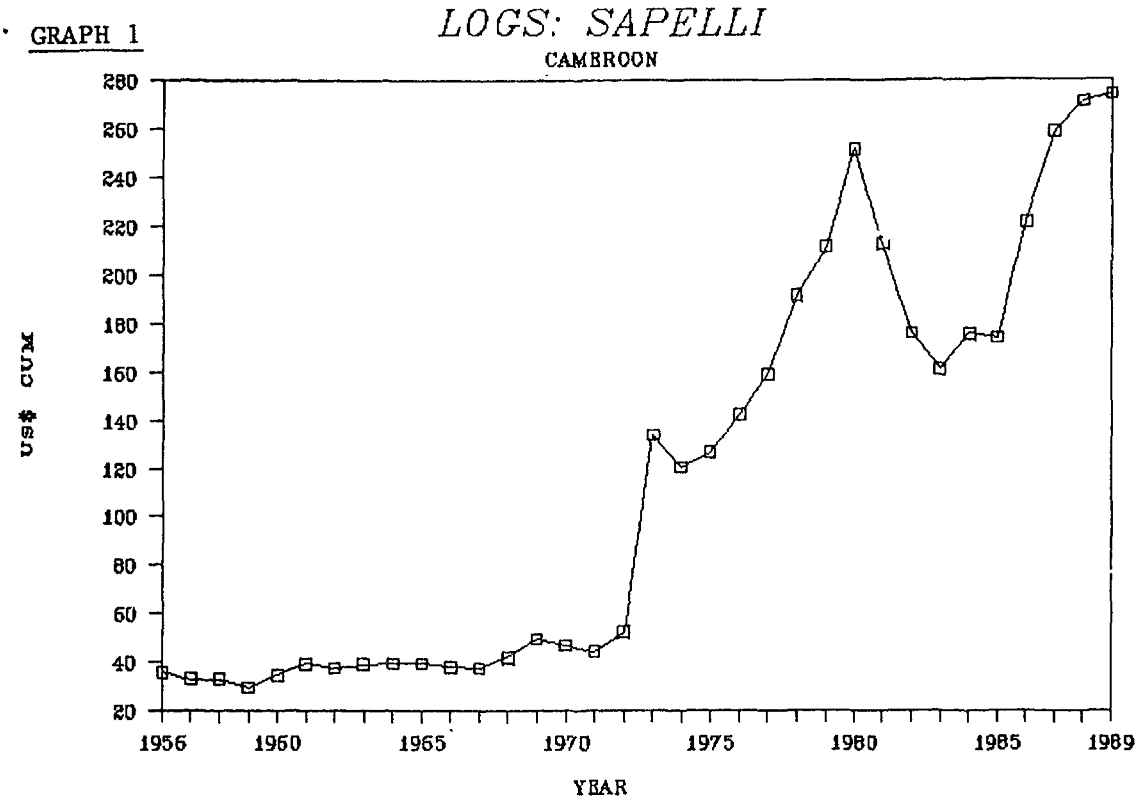
All data series are quarterly.

16. The three prices for African logs are the FOB prices reported by French importers. The sawnwood price is for Malaysian sawnwood in France,

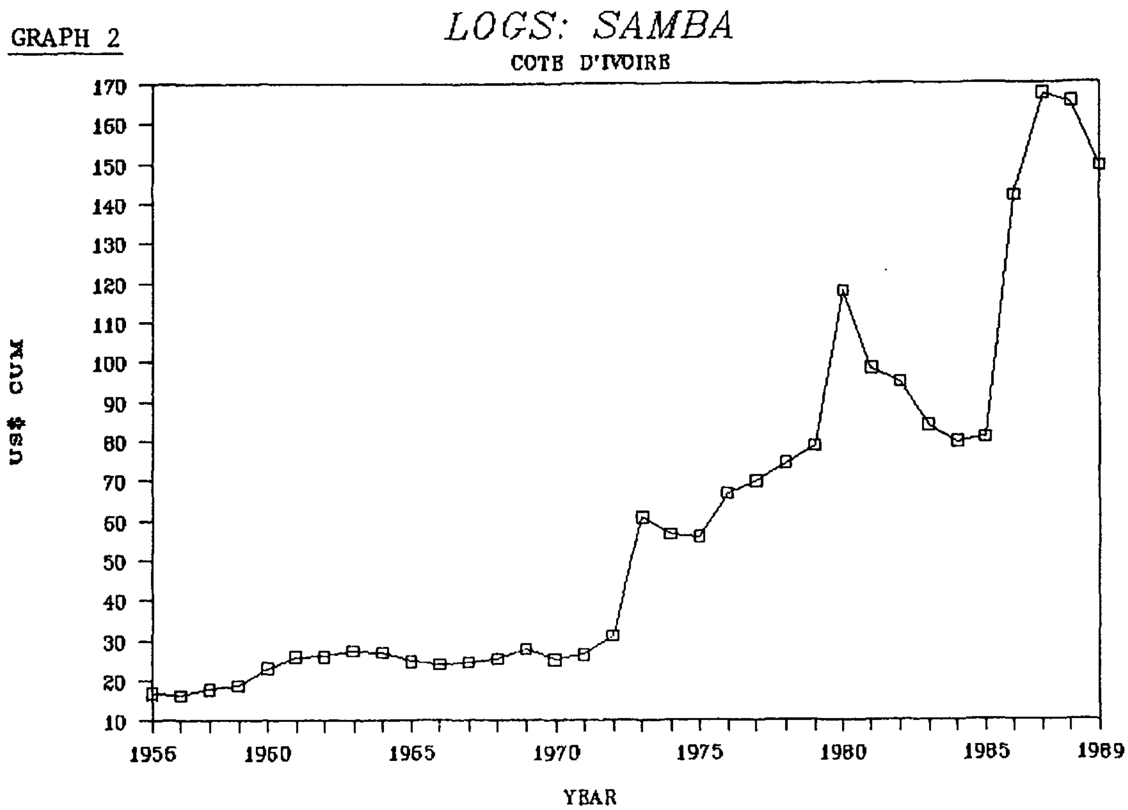
again as reported by French importers. About 66% of European imports of sawnwood come from Southeast Asia with a little less than half of that coming from Malaysia. Sawnwood imports from Africa and South America account for around 28% and 6% respectively. Japan is the largest importer of tropical plywood, absorbing about 30% of world tropical plywood exports; Japan is also the largest importer of tropical logs used for plywood production. On a world level, African timber producers export little sawnwood and plywood. African sawnwood and plywood exports account for about 6.5% and 1.5% respectively of the world exports for these two commodities. These shares have also been pretty much unchanged during the last 15 years.

17. Graphs 1 to 7 plot annual observations of the tropical timber price. It can be seen that prices for all logs, sawnwood and plywood remained quite stable throughout the early seventies, with a substantial increase during 1973-1974, and again in 1979-80 and 1987-88. While price increases in the earlier two periods (1973-74 and 1979-80) can be related to the price increases in almost all commodities, the most recent period of increasing prices can be related on the one hand to the restrictions by producing countries on exports, primarily of logs (in the case of Indonesia, the Philippines, Peninsula of Malaysia, and Brazil) but also processed products (recently, sawnwood from Indonesia), and, on the other hand, to the boom in industrial production in the 1987-88 period. Thoughts about export restrictions are also prevalent in Africa but as of this writing no action has been taken. While supply restrictions have been increasing, apparent consumption has been stable, despite the price increases. In Japan, during 1987 and 1988 consumption of logs and sawnwood increased substantially as housing and, more generally, construction boomed.

GRAPH 1

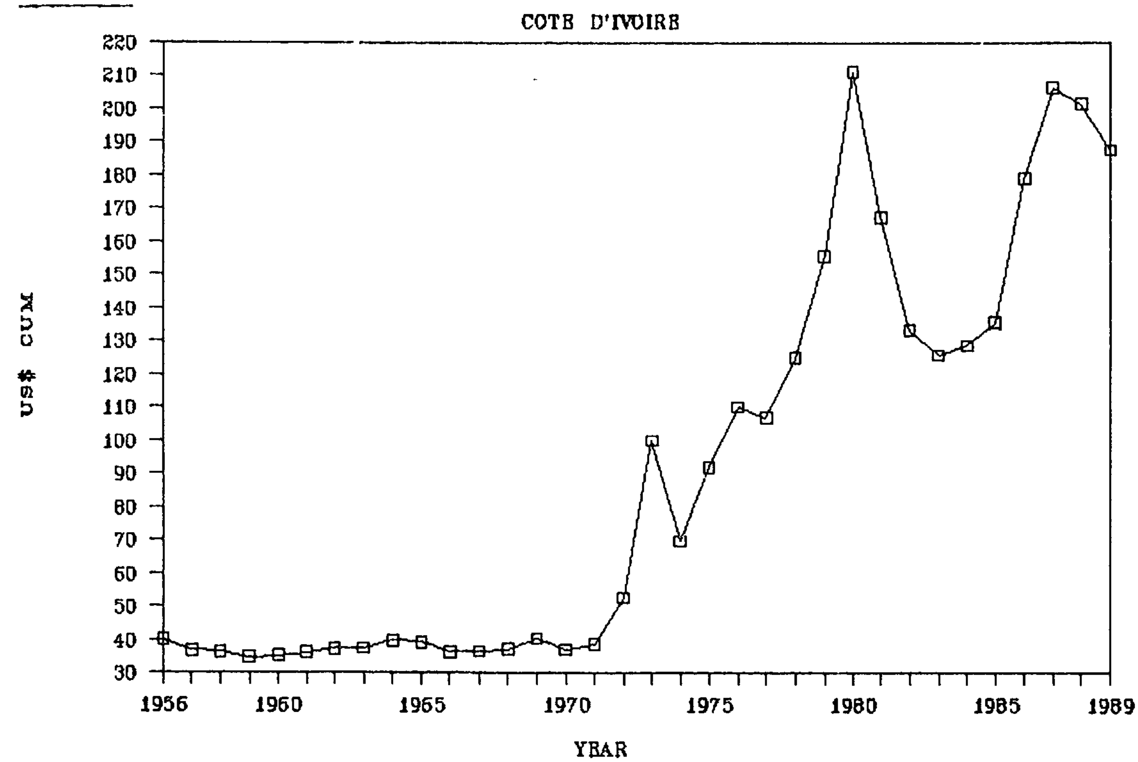



GRAPH 2



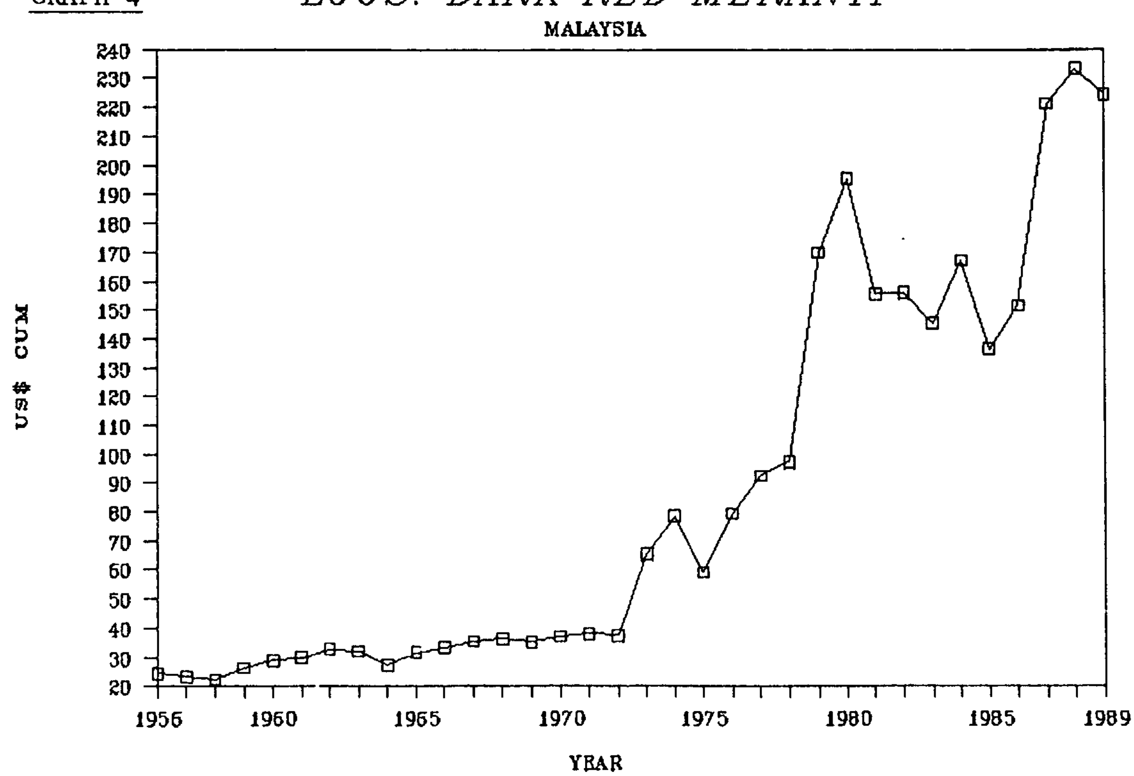
GRAPH 3

# LOGS: NIAGON

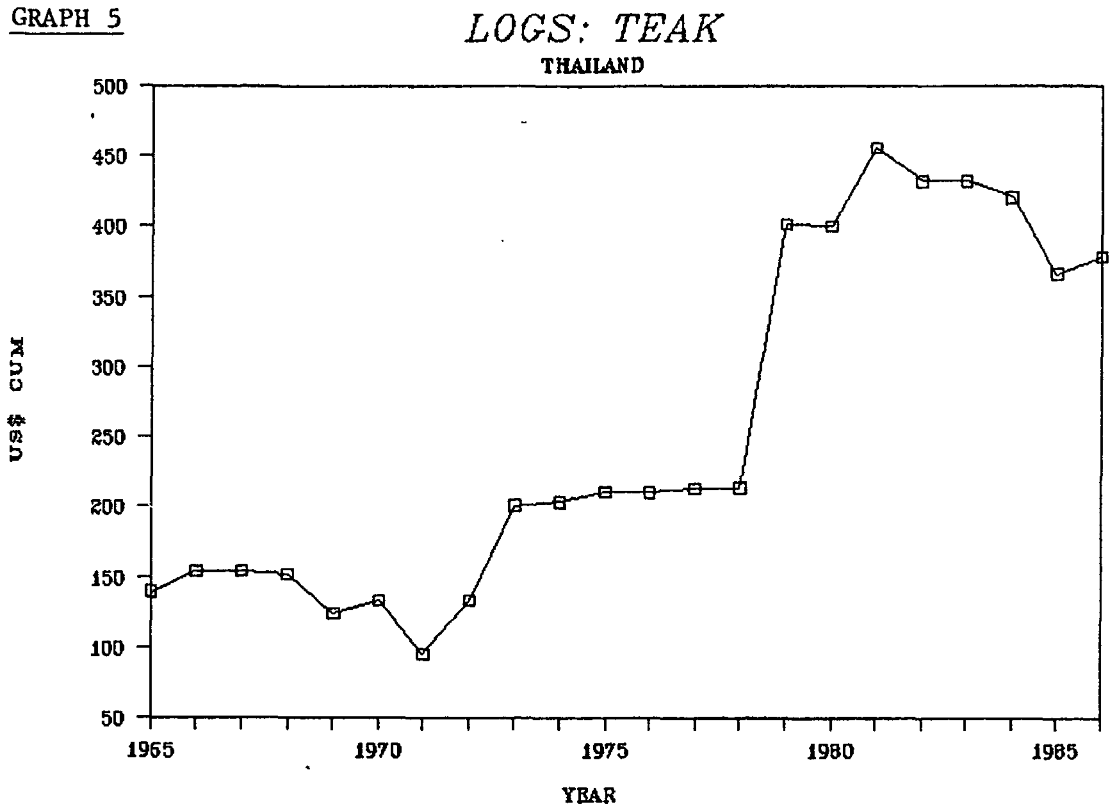



GRAPH 4

# LOGS: DARK RED MERANTI



GRAPH 5


LOGS: TEAK
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300
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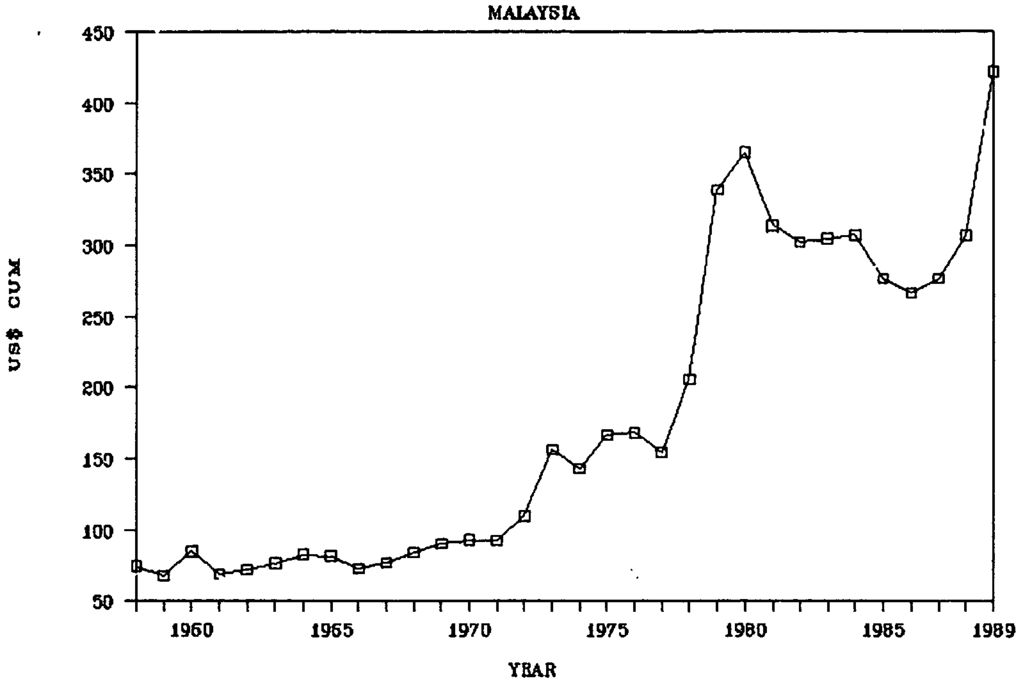
100
50
US$ CUM
1965
1970
1975
1980
1985
YEAR

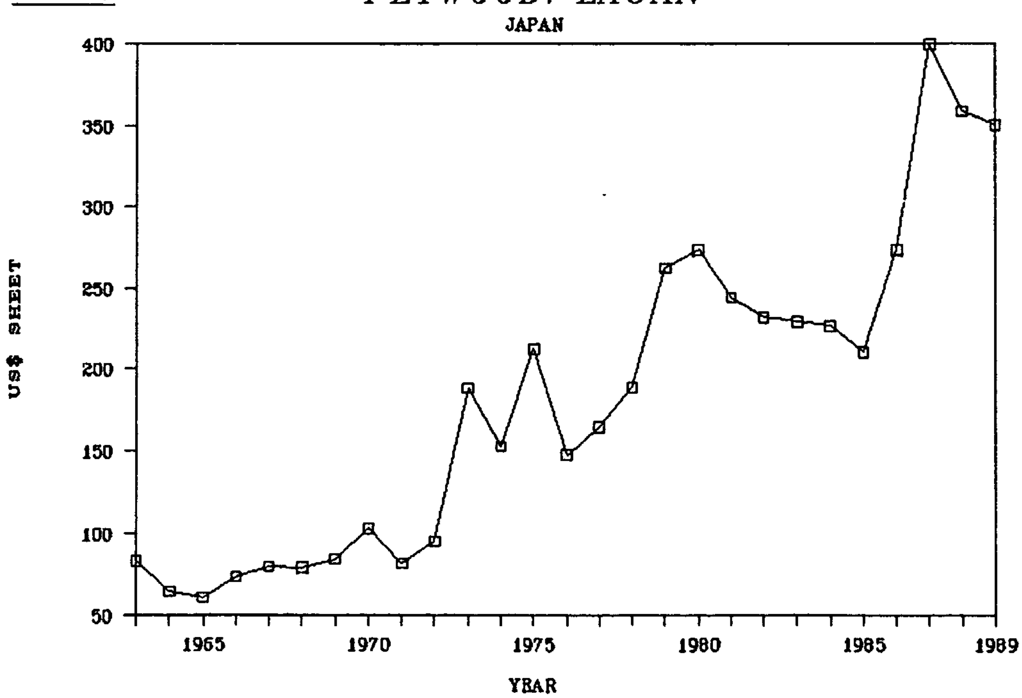
GRAPH 6

## SAWNWOOD: DARK RED MERANTI




GRAPH 7

## PLYWOOD: LAUAN



## III. EMPIRICAL RESULTS

### A. Integration Unit Root Tests

18. To test whether tropical timber prices move together in the long-run is equivalent to testing whether these prices are cointegrated. However, before testing for cointegration, it is necessary to establish that these prices are integrated of the same order. The order of integration is inferred by testing for the unit roots. The unit root tests applied are the ones described in Section I of the paper. The results from these tests are presented in Table 1 for the series in levels and Table 2 for the series in first differences. In Table 1, the line (t) under each price gives the Phillips test statistic. For all series, with the exception of plywood, the existence of a unit root could not be rejected. In Table 1, even at the 90% confidence interval none of the test statistics exceeded their critical values. The results of the Phillips test show that all price series are correctly identified as I(1), with the exception of plywood. For plywood, both the DF and ADF tests reject the hypothesis of a unit root even at the 99% confidence interval. What the application of the Phillips test shows, is that plywood could be misspecified as being I(1) while being white noise following a deterministic trend. The implication of this result is that the plywood price cannot be cointegrated with any other timber price since it possesses different intertemporal properties. In Table 2 the unit root tests for the price series in first differences are presented (with the exception of plywood) and they show that for all the differenced series the existence of a

Table 1: INTEGRATION UNIT ROOT TEST RESULTS FOR TROPICAL TIMBER PRICES

(prices in levels)

| Price Series | | CRDW | DF | ADF | Lags /b |
|---|---|---|---|---|---|
| Meranti | | 0.08 | -0.85 | -0.75 | 1 |
| | (t) /a | 0.53 | -2.29 | -2.51 | 1 |
| Teak | | 0.15 | -0.84 | -0.76 | 2 |
| | (t) | 0.64 | -1.98 | -2.56 | 2 |
| Sapelli | | 0.08 | -0.90 | -0.91 | 1 |
| | (t) | 0.42 | -2.17 | -2.62 | 2 |
| Samba | | 0.12 | -0.16 | -0.45 | 1 |
| | (t) | 0.54 | -2.29 | -2.83 | 1 |
| Niagon | | 0.12 | -0.49 | -0.71 | 1 |
| | (t) | 0.57 | -2.58 | -2.53 | 1 |
| Sawnwood | | 0.07 | -0.38 | -0.48 | 1 |
| | (t) | 0.55 | -2.08 | -2.83 | 1 |
| Plywood | | 0.16 | -1.14 | -0.86 | 1 |
| | (t) | 1.24 | -3.54 | -3.43 | 1 |
| | Critical values at 90% confidence internal | 0.32 | 3.03 | 2.84 | |

/a The line (t) below each price series refers to the regression $X_t = a + bt + u_t$.

/b Lags refers to the number of lags in the ADF test.

Table 2: INTEGRATION UNIT ROOT TEST RESULTS FOR TROPICAL TIMBER PRICES

(prices in first differences)

| Price Series | CRDW | DF | ADF | Lags /a |
|---|---|---|---|---|
| Meranti | 1.97 | -4.66 | -4.62 | 1 |
| Teak | 2.13 | -4.54 | -2.44 | 2 |
| Sapelli | 1.73 | -4.19 | -3.28 | 1 |
| Samba | 1.77 | -4.87 | -4.15 | 1 |
| Niagon | 1.81 | -5.00 | -4.42 | 1 |
| Sawnwood | 1.22 | -2.86 | -3.59 | 1 |
| Critical values at 90% confidence interval | 0.32 | 3.03 | 2.84 | |

/a Lags refers to the number of lags in the ADF test.

unit root is overwhelmingly rejected since the test statistics for all the tests are well above the critical values even at the 99% confidence interval.

19. Alternatively to testing for trend in the series as in Table 1, restrictions on the coefficients of equation (6) were imposed and tested by using the F-test. The restriction that c = 1 and b = 0, i.e., acceptance of the presence of a unit root, could not be rejected for any of the series. All F-statistics were way below the critical level even at the 75% level of significance. This result holds also for plywood, providing contradictory results with the test procedure used previously. Because of biases associated with the F-statistic in this case, the results using the DF and ADF test are preferred and thus plywood prices are considered to be white noise around a deterministic trend.

20. F ·ther tests based on Perron's (1989) suggested methodology were performed to test whether the time trend in equation (6) has an exogenous shift in its level and an exogenous change in its slope. The tests are based on imposing restrictions on the coefficients of equation (7). The hypothesis tested is whether 1973 was the year of the ch^nge. 1973 was chosen since it was the year of the first oil shock and also a boom year for most primary commodity prices. Furthermore, by visually examining the price series in Graphs 1 through 7 it can be observed that after 1973 prices started escalating and also became more volatile. Table 3 presents the t-statistics on the estimated parameters of regression (7). Recall that under the null

Table 3: UNIT ROOT TESTS, ALLOWING FOR A STRUCTURAL BREAK

Regression: $Y_t = a + b\,DU + cDT + dt + eX_{t-1} + \sum_{i=1}^{n} f_i X_{t-i} + U_t$

| Price Series | a | b | c | d | e /a |
|---|---|---|---|---|---|
| Meranti | 1.61 | -2.64 | 3.14 | 0.74 | -2.36 |
| Teak | 0.34 | -0.30 | 0.92 | -0.77 | -1.67 |
| Sapelli | 1.23 | -0.52 | 2.08 | 0.65 | -1.44 |
| Samba | 1.68 | -2.49 | 2.96 | 0.58 | -1.70 |
| Niagon | 1.71 | -1.24 | 2.11 | 0.44 | -1.86 |
| Sawnwood | 1.20 | -1.80 | 2.13 | 0.55 | -0.25 |

/a The t-statistic reported under e is for the hypothesis e = 1 and it is not distributed according to the standard t-distribution. The critical value for e is -4.24 at 95% the confidence interval (see Perron, (1989) p. 1377, Table VI.B.)

Notes: With the exception of the coefficients of the lagged dependent variable, for all other coefficients the standard t-distribution critical values can be used.

hypothesis of a unit root process the following conditions have to hold: a ≠ o (in general), b ≠ o (in general), c ≠ o, but more importantly, d = 0, and a = 1. The results of Table 3 show that the unit root hypothesis cannot be rejected since for all cases e ≠ 1 and d ≠ 0. . Regarding the structural break, the results are a bit mixed. For all cases, except teak, there is a trend factor beginning 1973, since the hypothesis c ≠ 0 was accepted for all cases. On the other hand, there is no statistical evidence for a shift in the level, since the hypothesis b ≠ 0 was rejected in all cases. In summary, after allowing for a break in both the levels and the trends after 1973, the hypothesis of the presence of a unit root could not be rejected, i.e., since the hypotheses e ≠ 1 and d = 0 could not be rejected, the series are I(1) even given the presence of a change in the trend beginning in 1973.

## B. Cointegration Unit Root Tests

21. All integration unit root tests fail to reject the existence of a unit root for all tropical timber prices with the exception of plywood. Given these results, one can proceed to the cointegration tests. The test procedure is described in Section I and the test results are presented in Table 4. The cointegration results show that all tropical timber prices are cointegrated with the exception of teak. The hypothesis that teak prices are cointegrated with all other prices was rejected at the 90% level of significance. The reason for this result could be that teak prices are domestic prices within Thailand and are somewhat isolated from the other tropical timber prices traded in the world markets. An additional problem with the teak price series

Table 4: COINTEGRATION UNIT ROOT TEST RESULTS /a

| | CRDW | DF | ADF | | |
|---|---|---|---|---|---|
| Critical Level 90% | 0.32 | 3.03 | 2.84 | | |
| Critical Level 95% | 0.39 | 3.37 | 3.17 | Lags /b | $\bar{R}^2$ /c |
| **Meranti** | | | | | |
| Sapelli | 0.85 | -2.95 | -2.87 | 2 | 0.93 |
| Niagon | 1.38 | -3.96 | -3.31 | 2 | 0.94 |
| Samba | 1.15 | -3.47 | -3.60 | 2 | 0.93 |
| Teak | 1.46 | -3.33 | -2.80 | 4 | 0.92 |
| Sawnwood | 1.15 | -3.33 | -4.15 | 2 | 0.92 |
| **Sapelli** | | | | | |
| Niagon | 1.19 | -3.47 | -4.76 | 2 | 0.98 |
| Samba | 0.55 | -2.15 | -2.88 | 2 | 0.92 |
| Teak | 0.80 | -2.18 | -2.67 | 4 | 0.80 |
| Sawnwood | 0.89 | -2.70 | -3.63 | 2 | 0.89 |
| **Niagon** | | | | | |
| Samba | 0.58 | -2.02 | -2.41 | 2 | 0.93 |
| Teak | 0.91 | -2.37 | -2.83 | 5 | 0.82 |
| Sawnwood | 1.09 | -2.95 | -4.31 | 2 | 0.89 |
| **Samba** | | | | | |
| Teak | 0.86 | -2.43 | -2.32 | 4 | 0.83 |
| Sawnwood | 0.80 | -2.58 | -3.83 | 2 | 0.83 |
| **Teak** | | | | | |
| Sawnwood | 1.06 | -2.66 | -2.80 | 5 | 0.93 |

/a The cointegration regression is: $Y_t = a + KY_t + Z_t$

/b "Lags" refers to the number of lags of the ADF test.

/c $\bar{R}^2$ refers to the adjusted $R^2$ of the cointegration regression.

is its relatively smaller sample size (a 22 year-span versus more than 30 for the other series), which could have, but not likely, caused a loss in the power of the tests.

22. The result that most of the tropical timber prices in the sample are cointegrated means there exists a special relationship between them. If in the short-run these prices tend to move apart, in the long-run they will move together. What pulls these prices together could be market forces, for example, the high degree of substitutability between them. The fact that the sawnwood price is cointegrated with all log prices is also to be expected since sawnwood is basically the first stage of processing of logs.

23. Cointegration has also implications about forecasting. Yoo (1986) has shown that the long-run optimal forecast of two cointegrated variables will "hang together" and therefore will produce a better forecast than any other univariate forecast. That is, long-run projections of a tropical timber price have implications for the long-run projections of the other tropical timber prices cointegrated with it.

24. Another implication of the findings is that tropical log prices from the two different producing regions move together in the long-run. Thus, despite the traditional regional pattern of the trade in tropical logs, the markets are interdependent--at least over the long term.

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