NEW GUINEA GOLD OR BUST:
DETECTION OF TRENDS IN THE QUALITY OF
COFFEE EXPORTS IN PAPUA NEW GUINEA

Chai McConnell, Alicia Rambaldi and Euan Fleming

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Many commentators in the coffee industry in Papua New Guinea, including managers in the Coffee Industry Corporation, have perceived a long-term decline in the quality of coffee. This, it is thought, has depressed domestic prices and perhaps damaged the reputation of Papua New Guinea as a producer of high quality coffee. Two tests were undertaken to determine the validity of this perception, first on the domestic price system of A, X and Y grade coffee only and, second, on the world indicator price of Other Milds and the domestic price system of A, X and Y grade coffee.

The results of the first test reveal two cointegrating relationships in the domestic price system. The first vector reports long-run relationships between the prices of A, X and Y grade coffee in domestic marketing system; the second reveals the influence of the global coffee market on domestic coffee prices. The second cointegration test indicates that, in the long run, no relationship exists between the world indicator price and the prices of A, X and Y grade coffee.

The implication of the first test is that coffee quality does have a significant long-run impact on the prices received for domestic grades of coffee. The second test result reveals long-term deviations of the prices of the domestic grades of coffee from the world indicator price. This implies that the prices of all domestic coffee grades are being increasingly penalised in the world market. The most plausible cause is deteriorating coffee quality.
Background to the Research Problem

Coffee production is the major form of cash cropping in the agricultural sector in Papua New Guinea (PNG). With over 70 per cent of output supplied by smallholder producers, it is a crucial source of rural income for the indigenous population. In remoter areas, it is often the only legal cash-earning activity available. Attention in this paper is focused on price-quality relations in the coffee industry. Inter-grade variations in coffee price differentials are examined, and the proposition is tested that quality deterioration over time has led to reduced returns to coffee exports from PNG through price discounting in world markets.

PNG produces coffee that is classified by the International Coffee Organization (ICO) as Other Milds (OM) arabica, plus a small amount of robusta (which for the purpose of analysis will be ignored). Coffee production is almost wholly export-oriented. Supplying around one per cent of the world's coffee, PNG is invariably a price taker in the international market.

Domestic prices for PNG arabica coffee in real terms recently fell to their lowest levels since commercial production began in the early 1950s. Despite an upturn in world coffee prices in 1994, severe hardship is still being experienced by all participants in the coffee industry. The Coffee Industry Corporation (CIC) attributed the fall in coffee prices to several exogenous factors (Smith 1992, p. 1). However, endogenous variables can also contribute to depressed domestic prices. The most important candidate, signified by the CIC, is coffee quality. It is perceived by many in the industry that the quality of PNG coffee has deteriorated. Proponents of this view cite declining domestic prices, decreasing production of the higher quality coffee grades and an increased production of lower quality coffee in support of this claim. It is postulated that this has not only reduced export prices below attainable levels but also damaged, perhaps irreversibly, PNG's international reputation as a producer of high-quality coffee.

The first objective is to investigate long-run inter-grade price movements using cointegration analysis by examining movements in the prices of the three main coffee grades in PNG - A, X and Y grade. If no long-run relationships exist in the domestic price system of A, X and Y grade coffee, then quality is the most likely cause of divergences in inter-grade price differentials. On the other hand, existence of a long-run relationship implies that the prices of the higher grades of coffee and the prices of Y grade coffee hold an equal relationship to which they converge.

The second objective of the study is to examine the impact of the world price of OM coffee (measured by the ICO Other Milds world indicator price) upon the prices of A, X and Y grade to determine how significant international prices are to the formation of domestic coffee prices. If no long-run relationship exists between the two price systems, the implication that the prices of A, X and Y grade coffee deviate from the indicator price possibly because of quality deterioration or some other factor in the global coffee market. Conversely, a long-run relationship between the OM price and the domestic price of A, X and Y grade coffee implies that
the relationship between the price series of domestic grades and the OM price are stable, and coffee quality may not have declined in the long run.

Quality Deterioration in Coffee

The issue of deteriorating coffee quality has been central to debate about the future of the coffee industry in PNG. The matter is considered of such importance in the industry and among policy makers that an abundance of literature has been generated on the subject. Cartledge (1978, p. 18) stated that quality issues were first raised at the inception of the industry in 1956. Publications by CIC and its predecessor, the Coffee Industry Board (CIB), are an excellent source of information on these issues. Its quarterly market reports and annual statistical reviews have consistently concentrated on the problem of quality deterioration in the PNG coffee industry (e.g., CIB 1979). More recently, Mitio (1992, p. 9) stated that 'the CIC is taking the criticisms of poor quality from smallholder ...coffee seriously'.

Concern over deteriorating quality provoked the Coffee Research Institute (CRI) of the CIC to publish several articles. The CRI Newsletter provides important information about the establishment, management and processing aspects of coffee production. Recently, economic policy proposals have been published and reforms implemented, suggesting tighter grading controls in an effort to improve Y grade coffee (Calvert 1992, pp. 26-30).

While many newspaper and consultancy reports allude to the importance of quality, only the McGowan report (1989), which was commissioned by the Department of Agriculture and Livestock, discussed quality in detail. The report considered the main factors influencing quality and methods to improve processing.

Kuri (1991) examined how the quality of PNG coffee fared when subjected to liquoring tests. He provided invaluable information concerning quality control, processing techniques and an assessment of cup quality. Pickstock (1992, p. 21) described coffee quality in the international, specifically African, context. He implied that high-quality coffees are increasingly in demand and that the previous markets of lower-quality coffee, such as the former Soviet Union and Eastern Europe, have diminished due to foreign exchange shortages. Describing the quality problems faced by African producers, Pickstock's remark is applicable to the situation confronting PNG. He concluded that in an increasingly competitive market, improved quality will help producers to remain in operation.

While all these studies provide valuable information on factors influencing coffee quality and stressed the significance of quality to the industry, none undertook any quantitative analysis of relations between price and inter-grade quality differences.
Coffee Production in Papua New Guinea

The production of coffee is characterised by three distinct modes, smallholdings, blockholdings and estates. The post-harvest activities of handling, transport, processing, roasting and export are undertaken by private firms.

From its introduction in the late 1890s, coffee production has rapidly become an important contributor to the economic and cultural development of PNG. Only two varieties of coffee, arabica and canephora (robusta), are commercially important in PNG. Within the tall arabica variety, blue mountain (typica), bourbon, mondo novo and arusha are cultivated. High-yielding dwarf varieties, namely caturra and the rust-resistant catimor, are also grown, predominantly cultivated on estates and blockholdings because of their high input requirements.

Approximately 270,000 smallholder households grow coffee, contributing some 70 per cent of total output (Temon 1993). Harding, Bleeker and Freyne (1986, pp. 21-23) observed that smallholder coffee production is essentially a low-input activity. Village gardens are generally less than 10 ha, with the majority smaller than 0.05 ha. Average tree densities range from 200 to 300 trees/ha but some densities are in excess of 2500 trees/ha (Dick 1976). Larger, family-operated gardens occasionally employ seasonal labourers. Management procedures such as shade provision, drainage and weeding are of a low yet variable standard and, as a result, yields vary between 0.06 t/ha and 1.15 t/ha with an average of 0.4 t/ha (Hassall and Associates 1982). Approximately 20 per cent of output is sold as cherries with the remainder undergoing small-scale, manual processing up to the parchment stage (Fleming and Antony 1993).

Smallholder coffee plots are communally owned according to tribal law and tradition, with very few titles issued. Coffee gardens are often intercropped with food and root crops such as sugar cane, pineapples, sweet potato and leafy vegetables. Few legal alternatives to coffee production exist in remote areas although horticultural crops have recently provided a relatively successful supplementary cash cropping activity to coffee in the wake of depressed coffee prices.

Blockholdings of around 20 ha in size are relatively new developments in the industry. The 250 or so holdings that exist supply 5 per cent of total production (Temon 1993). Initiated in 1979, blockholdings represented an attempt to organise smallholders into business groups to capture gains from economies of scale that were thought to exist in high input/output production activities. They mainly employ hired labour although occasional family labour input is provided. The land used is still communally owned, but titles were issued as a prerequisite for credit access. A further requirement was that blockholdings had to be managed by professional management agencies until the coffee became fully bearing (Harding et al. 1986, p. 20).
Estates have been defined as 'formal companies of up to 1,000 hectares or more ... located on land alienated from communal ownership by a long lease agreement' (McGowan International 1989, in Fleming and Antony 1993, p. 20). Approximately 60 estates averaging about 300 ha currently exist. Although relatively small in number, the estate sector contributes 25 per cent of total output (Temon 1993). Estates require high levels of managerial and entrepreneurial skill for successful operation. Widespread use of chemical fertilisers, pesticides and herbicides generally (but not always) results in high levels of land preparation and plant husbandry. Tree densities averaged 2640/ha in 1991/92 with yields averaging 1.55 tonnes gbe/ha (B. Temon, CIC, 1993, personal communication), but yields above 2.5 tonnes/ha are regularly achieved (Munnall and Densley 1980).

Coffee Buying, Processing and Exporting in Papua New Guinea

Roadside buyers purchase most of the coffee produced by smallholders, operating either as individual entrepreneurs or on a contract basis. Smith (1991, p. 5) estimated in excess of 500 roadside buyers in operation but, in peak production periods, may be well above that number (J. Leahy, coffee grower and processor, 1993, personal communication). They mostly purchase cherry or parchment coffee and, after processing cherry to parchment, resell the coffee at central buying stations or direct to factories.

Roadside buyers have been an issue of concern for many years because of the perception that prices offered by them do not transfer government bounty payments. Temon (1993) confirmed this contention when he found that three consecutive increases in bounty payments were not proportionally transferred in the roadside price. However, analysis by CIC found evidence that bounties are transmitted in daily prices, and, if not transmitted fully at first, are eventually transmitted in full (Fleming and Antony 1993).

There are at least 50 registered processors in PNG who process parchment into green bean. Around 20 have licences to process coffee that is produced by themselves and purchase only cherry coffee from other sources. The remaining processors are able to purchase cherry and parchment coffee from any source, about half of whom have coffee supplied primarily from their own estates.

Export of PNG coffee is regulated by the CIC under the Statutory Functions and Powers Act 1991. As of March 1993, there were 13 companies with exporting licences, with one company, Arabica's, specialising in roast exports. Of these 13 companies, five were operating under special conditions stipulated by the CIC (D.G.V. Smith, CIC, 1993, personal communication). Coffee exporters may be classified into three main groups: specialist exporters, partly integrated exporters and estate-based exporters (Smith 1991, p. 6). Specialist exporters supply around one-quarter of coffee exported, performing the marketing services of matching sellers of PNG green bean coffee with roasters overseas. Some value adding occurs where coffee is regraded before export.
Partly integrated exporters have some interest in processing facilities and in estates, as well as having an export licence. This category accounts for around two-thirds of exports. Estate-based exporters are vertically-integrated, being involved in all stages of production from cultivation to export. These companies export around one-tenth of total exports and around one third of the estate crop. There is also a small amount of roasted coffee exported, but it is excluded from consideration in the analyses which follow.

Model and Methods

The analytical model is outlined in this section. Details are provided of tests conducted to determine the non-stationarity of the variables of interest: A, X, Y grade PNG coffee prices and the OM international indicator price. Unit root tests are conducted to ascertain the statistical properties of the variables prior to further statistical analyses. The review of the econometric procedure undertaken in this study is very selective. A more complete analysis of the concepts used may be found in Charemza and Deadman (1992), Cuthbertson, Hall and Taylor (1992), Engle and Granger (1987), Engle and Yoo (1987), Johansen and Juselius (1990) and Enders (1995).

Tests were conducted to determine the presence of unit roots and non-stationarity using the SHAZAM Version 7.0 econometrics computer package. Two procedures were used: the standard 'augmented Dickey-Fuller' (ADF) test and the Phillips-Perron (PP) unit root test. Both testing procedures were undertaken but preference was given to the PP test as it is considered more robust with respect to heteroscedasticity and dependence of errors across time (Phillips 1987). Readers interested in the specifics of the tests conducted are referred to Enders (1995, Chapter 4) and the SHAZAM Econometrics Computer Program User's Reference Manual Version 7.0 (White 1993).

Cointegration analysis provides a means to test the possible long-run relationships between the prices of A, X, Y and OM grade coffee. A set of nonstationary variables form an equilibrium relationship if the variables cannot move independently of each other. The equilibrium implies that their stochastic trends must be linked, which necessitates cointegration.

Cointegration analysis permits short-run dynamics and long-run relationships to be formulated in the one model with the use of an error correction mechanism (ECM) framework. When variables are cointegrated, such as A grade and X grade coffee for example, their time path is influenced by the extent of any deviation from long-run equilibrium. By the Granger representation theorem, cointegrated variables can be represented through an ECM.

There are several ways to test for cointegrating relationships among a group of variables but, in general, most analyses of cointegration have used the bivariate test of Engle and Granger and the Johansen Method. This analysis uses the latter method as the Engle and Granger method has been recently recognised as being
subject to a number of limitations. They include concerns over the potential for 'small-sample bias' in parameter estimations, the fact that cointegration estimations are confined to pair-wise analysis and that the test does not have well-defined limiting distributions, resulting in an inability to provide straightforward testing procedures.

In comparison, the Johansen Method is deemed preferable to the Engle and Granger test as the multivariate approach suggests a maximum likelihood estimation procedure that enables estimates of all cointegrating vectors for a group of variables to be ascertained. In addition, the Johansen maximum likelihood method uses test statistics that have an exact limiting distribution that is the function of the single parameter. In so doing, it may offer important advantages over the bivariate two step estimator (Goodwin 1992, p. 118).

The Johansen Method of testing and estimating cointegrating relationships may be illustrated considering the following three-dimensional VAR(2) model using A, X and Y grade coffee prices as variables. The three-dimensional VAR (2) in matrix notations is:

\[
\begin{bmatrix}
A_t \\
X_t \\
Y_t
\end{bmatrix} = \begin{bmatrix}
\delta_1 \\
\delta_2 \\
\delta_3
\end{bmatrix} + \begin{bmatrix}
\phi_{11} & \phi_{12} & \phi_{13} \\
\phi_{21} & \phi_{22} & \phi_{23} \\
\phi_{31} & \phi_{32} & \phi_{33}
\end{bmatrix}\begin{bmatrix}
A_{t-1} \\
X_{t-1} \\
Y_{t-1}
\end{bmatrix} + \begin{bmatrix}
\phi_{11} & \phi_{12} & \phi_{13} \\
\phi_{21} & \phi_{22} & \phi_{23} \\
\phi_{31} & \phi_{32} & \phi_{33}
\end{bmatrix}\begin{bmatrix}
A_{t-2} \\
X_{t-2} \\
Y_{t-2}
\end{bmatrix} + \begin{bmatrix}
\epsilon_{t1} \\
\epsilon_{t2} \\
\epsilon_{t3}
\end{bmatrix}.
\]

If the variables are non-stationary and cointegrated, then the VAR (2) model can be rewritten as an ECM where short-run dynamic fluctuations in the prices of A, X and Y grade coffee are functions of recent changes in the variables and in terms of deviations from a long-run equilibrium relationship between the price of A, X and Y grade coffee:

\[
\begin{bmatrix}
\Delta A_t \\
\Delta X_t \\
\Delta Y_t
\end{bmatrix} = \begin{bmatrix}
\delta_1 \\
\delta_2 \\
\delta_3
\end{bmatrix} + \begin{bmatrix}
\gamma_{11} & \gamma_{12} & \gamma_{13} \\
\gamma_{21} & \gamma_{22} & \gamma_{23} \\
\gamma_{31} & \gamma_{32} & \gamma_{33}
\end{bmatrix}\begin{bmatrix}
\Delta A_{t-1} \\
\Delta X_{t-1} \\
\Delta Y_{t-1}
\end{bmatrix} + \begin{bmatrix}
\Pi 
\end{bmatrix}\begin{bmatrix}
A_{t-2} \\
X_{t-2} \\
Y_{t-2}
\end{bmatrix} + \begin{bmatrix}
\epsilon_{t1} \\
\epsilon_{t2} \\
\epsilon_{t3}
\end{bmatrix}.
\]

An alternative specification is when the constant is included with the cointegrating relationship:

\[
\begin{bmatrix}
\Delta A_t \\
\Delta X_t \\
\Delta Y_t
\end{bmatrix} = \begin{bmatrix}
\gamma_{11} & \gamma_{12} & \gamma_{13} \\
\gamma_{21} & \gamma_{22} & \gamma_{23} \\
\gamma_{31} & \gamma_{32} & \gamma_{33}
\end{bmatrix}\begin{bmatrix}
\Delta A_{t-1} \\
\Delta X_{t-1} \\
\Delta Y_{t-1}
\end{bmatrix} + \begin{bmatrix}
\Pi 
\end{bmatrix}\begin{bmatrix}
A_{t-2} \\
X_{t-2} \\
Y_{t-2}
\end{bmatrix} + \begin{bmatrix}
\epsilon_{t1} \\
\epsilon_{t2} \\
\epsilon_{t3}
\end{bmatrix}.
\]

\(\Pi\) is a (3X3) matrix in model (2) or a (3X4) if the correct model is (3), and is called the impact matrix. The correct model specification can be tested using a likelihood ratio test. The matrix \(\Pi\) may be specified as a product of a two matrices, \(\alpha\) and \(\beta\), depending on its rank.
Given a system with three variables, the rank of $\Pi$ may be one, two or three.

- If rank $(\Pi) = 1$, then the impact matrix may be rewritten as the product of a $(3 \times 1)$ vector $\alpha$ and a $(1 \times 3)$ vector $\beta'$ for the case of model (2):

$$
\Pi = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} \begin{bmatrix} \beta_1 \\ 1 - \beta_2 \\ -\beta_3 \end{bmatrix}
$$

and the corresponding error correction model is:

$$
\Delta A_t = \delta_1 + \gamma_{11} \Delta A_{t-1} + \gamma_{12} \Delta X_{t-1} + \gamma_{13} \Delta Y_{t-1} + \alpha_1 (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \varepsilon_{1t}
$$

$$
\Delta X_t = \delta_2 + \gamma_{21} \Delta A_{t-1} + \gamma_{22} \Delta X_{t-1} + \gamma_{23} \Delta Y_{t-1} + \alpha_2 (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \varepsilon_{2t}
$$

$$
\Delta Y_t = \delta_3 + \gamma_{31} \Delta A_{t-1} + \gamma_{32} \Delta X_{t-1} + \gamma_{33} \Delta Y_{t-1} + \alpha_3 (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \varepsilon_{3t}
$$

with a cointegrating relationship linking $A$, $X$, and $Y$ grade prices given by:

$$
A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2} = v_t.
$$

- If rank $(\Pi) = 2$, there are two cointegrating relationships linking the variables. The specific relationship is:

$$
\Pi = \begin{bmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \end{bmatrix} \begin{bmatrix} \alpha_{12} \\ \alpha_{22} \\ \alpha_{32} \end{bmatrix}' \begin{bmatrix} 1 - \beta_{12} - \beta_{13} \\ 1 - \beta_{22} - \beta_{23} \end{bmatrix}
$$

and the ECMs become:

$$
\Delta A_t = \delta_1 + \gamma_{11} \Delta A_{t-1} + \gamma_{12} \Delta X_{t-1} + \gamma_{13} \Delta Y_{t-1} + \alpha_{11} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \alpha_{12} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \alpha_{13} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \varepsilon_{1t}
$$

$$
\Delta X_t = \delta_2 + \gamma_{21} \Delta A_{t-1} + \gamma_{22} \Delta X_{t-1} + \gamma_{23} \Delta Y_{t-1} + \alpha_{21} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \alpha_{22} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \alpha_{23} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \varepsilon_{2t}
$$

$$
\Delta Y_t = \delta_3 + \gamma_{31} \Delta A_{t-1} + \gamma_{32} \Delta X_{t-1} + \gamma_{33} \Delta Y_{t-1} + \alpha_{31} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \alpha_{32} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \alpha_{33} (A_{t-2} - \beta_2 X_{t-2} - \beta_3 Y_{t-2}) + \varepsilon_{3t}
$$
The variables $\Delta A_t$, $\Delta X_t$ and $\Delta Y_t$ are functions of changes in the previous period, and fluctuations from the long-run equilibrium relationships are defined by the cointegrating relationships:

\[ A_{t-2} - \beta_{12} X_{t-2} - \beta_{13} Y_{t-2} = v_{1t}, \]
\[ A_{t-2} - \beta_{22} X_{t-2} - \beta_{23} Y_{t-2} = v_{1t}. \]

That is, in a three-dimensional VAR model, cointegration exists when \( \text{rank} (\Pi) = 1 \), implying that there is one cointegrating relationship, or \( \text{rank} (\Pi) = 2 \), implying that there are two.

- If \( \text{rank} (\Pi) = 3 \) or \( \text{rank} (\Pi) = 0 \), then the variables of the three-dimensional model, the prices of $A$, $X$ and $Y$ grade coffee, are not cointegrated and no long-run equilibrium relationship exists between the variables.

The key of the Johansen testing procedure is to determine how many stationary linear combinations of the variables there are in the system. The number of linear combinations, denoted by \( r \), is the number of cointegrating relationships. Two tests can be used to determine \( r \), the Trace test and the Lambda max test. Both are based on the characteristic roots of the matrix \( \Pi \). The computer package CATS in RATS provides both values of the test as well as the individual estimates of the characteristic roots.\(^5\)

**Testing and Estimation**

*Data considerations*

The estimation procedures undertaken in the study use monthly data based on export receipts which were collated by CIC.\(^6\) The series covered 189 monthly observations over a 15-year period from January 1977 to September 1992. The prices for PNG coffee are calculated on average monthly free-on-board (FOB) prices with the OM indicator price ex-dock New York.\(^7\)

Prior to estimation, the data were deflated to real prices using the PNG consumer price index, adapted from data acquired from Bank of PNG financial reports and a previous study of the PNG coffee industry by Tautea (1992), with 1977 used as the base year. The data series for the ICO indicator price, OM, was deflated to real prices using the world GDP implicit deflator (World Bank 1993).

*Procedure*

Prior to conducting an econometric test for unit roots, some basic statistical tests were performed. The prices of $A$, $X$, $Y$ and OM coffee were plotted against time and examined to determine if the series exhibited any trends. The rationale for this procedure is that if a stochastic trend is displayed, the implication is that the series is non-stationary.
Tests for unit roots were undertaken by specifying the number of truncation lag parameters for the PP unit root test and the lag term in the ADF test. In all, eight lag lengths were selected for the prices of A, X, Y and OM coffee in an attempt to pick up all the residual correlations. The number of lags was determined using the Akaike information criterion (AIC) prior to testing for unit roots. This procedure involved determining the lag length where the AIC was minimised. At this point, it is expected that the test has the correct power and size to detect unit roots.

The test procedure for cointegrating relationships is undertaken using the Johansen method. Because this is a multivariate test, the approach enables testing for cointegrating relationships between all variables. The prices of A, X and Y grade coffee were tested to determine the presence of long-run relationships between the domestic grades of coffee.

Similarly, A, X, Y and OM coffee prices were tested to investigate the presence of cointegrating relationships between the domestic and international price of coffee. As well, a further test was conducted to ascertain the presence of the OM price in the cointegrating relationship with A, X and Y grade prices.

A feature of cointegration analysis is the one-to-one relationship between cointegrating vectors and ECMs if the residuals of the ECM equations are not autocorrelated. Therefore, a likelihood ratio test was used to determine the number of lags to be included in the model such that the residuals appear white noise. The test was conducted with the model in VAR form (see equation (1)) and it takes the form:

$$LR_1 = (T- c) (\ln|\Sigma_k| - \ln|\Sigma_{k+1}|)$$

where

- $k$ = number of lags in each equation of the system
- $T$ = number of parameters estimated in each equation of the unrestricted system ($k+1$ lags)
- $\ln|\Sigma_k|$ = natural logarithm of the determinant of the variance/covariance matrix of the residuals.

$LR_1$ has an asymptotic $\chi^2$ distribution with degrees of freedom equal to the number of restrictions in the system. When $LR_1$ is larger than the $\chi^2$ critical value at the specified significance level, the conclusion is to reject the model with $k$ lags in favour of that with $k+1$ lags.

**Empirical Results**

Estimates of the various test statistics outlined above are reported in this section. Table 1 provides a description of the statistics and coefficients that are reported throughout the section. The first test for unit roots was carried out following the observation that the data series for A, X, Y and OM coffee prices do
appear to exhibit a trend, implying that the series is non-stationary (or has unit roots). This conclusion was supported by the results of the empirical analysis.

Tables 2 to 8 report results of the Johansen multivariate test for cointegrating relationships. The first test was conducted to determine the presence of long-run relationships between prices in the domestic price system and the second the long-run relationships between the OM price and domestic prices. The results of the Johansen test on the domestic prices of A, X and Y grade coffee are reported in Tables 2 and 3. This procedure tests the presence of cointegrating relationships by testing the rank of the matrix $\Pi$. Table 2 presents the results of the LR$_1$ test for the lag length specification, while Table 3 presents the results of the Trace statistic. As explained above, the model can be specified as in equation (2) or (3) depending on whether a constant is included inside or outside the cointegration space. This test is a likelihood ratio and the model is specified as in equation (3) under the null hypothesis. In all cases reported in this study, we failed to reject the null hypothesis; therefore, all results are based on specification (3).

The results show that two cointegrating or long-run relationships exist between the price series of A, X and Y grade coffee (see Table 3). The first cointegrating vector is attributed to long-run relationships within the domestic sector of the coffee marketing system only. The second cointegrating vector reports the influence of international variables on prices in the domestic sector. The normalised estimates (for the A grade prices) of the two cointegrating vectors are presented in Table 4. Note that $\alpha$ is (3×2) and $\beta$ is (2×4) for the domestic prices system.

The first cointegrating vector indicates an inverse relationship between the prices of A and X grade coffee and a positive relationship between A and Y grade prices. In other words, the long-run tendency is that, as the price of A grade coffee rises, the price of X grade coffee falls in an almost unitary manner. As the price of A grade coffee rises, the price of Y grade coffee rises by less than unity.

The results of the second Johansen test procedure examining the existence of cointegrating relationships between the domestic and international price system are reported in Tables 5 to 7. Table 5 presents the results of the LR$_1$ specification test, where $k$ was determined to be 4. Table 6 presents the Trace test procedure from which the conclusion is reached that the number of cointegrating relationships is unchanged with the inclusion of the OM price in the system. Table 7 contains the estimated values of $\alpha$ and $\beta$. The estimates reveal that even though the OM price is included, the vectors report an almost identical result as the test procedure for cointegrating relationships between the price series of A, X and Y grade coffee. Indeed, the impact of the OM price appears insignificant.

To study further the relationship between the domestic and international price system, a further test was conducted. The results are presented in Table 8. A likelihood ratio was computed to test the hypothesis that the $\beta$ coefficients on the international price series are not statistically different from zero (i.e., $\beta_{14} = \beta_{24} = 0$).
This result is confirmed. In other words, the OM price does not have a steady state or equilibrium relationship with the domestic price system.

Interpretation of Results and Policy Implications

On the basis of the empirical results reported in the previous section, there is evidence to suggest that long-run relationships exist between combinations of AX, AY and XY grade domestic coffee prices. The conclusion that long-run relationships exist between the domestic price series is unsurprising given policy-induced distortions that have an impact upon the whole PNG coffee industry.

In particular, perhaps the most significant policy directive that CIC, and its predecessor, CIB, has been charged to implement that has contributed to this relationship is the system of bounty payments to producers, regardless of inter-grade quality differences. Bounty payments for A grade coffee are equivalent to payments for Y grade coffee despite quality differences between the two types of coffee. This policy is still being pursued despite its effect of misallocating resources to the production of lower quality coffee.

Of the two cointegrating relationships found in Tables 3 to 5, the first vector captures the long-run relationship between the domestic coffee marketing system only, and the second the influence of international market factors on domestic coffee prices. As Table 4 reveals, a significant and inverse linear relationship exists between A and X grade prices, and a significant positive relationship exists between A and Y grade prices. The inverse relationship between A and X grade coffee prices may be attributed to the substitutability between these essentially estate grades of coffee. The A and X grades of coffee are not homogeneous because of characteristic differences in acidity, body and flavour. However, given that consumers’ tastes and preferences for coffee are generally conservative, roasting agencies buying PNG coffee through exporting companies are on the whole loath to change the composition of their blends. Because of this, A and X grade coffee are only partial substitutes for one another. It depends on the relative scarcities of supply for the higher quality coffee and whether relative inter-grade price differentials are close. As A and X grade coffee are both produced mainly in the estate sector, the inverse relationship might not be anticipated as general economic theory states that relations between grades are positively correlated. However, there are two reasons why the inverse relationship exists.

First, prices of all grades are unaffected by domestic supply of grades because PNG producers are price takers and inter-grade price differentials are formed in the world coffee market. Hence, price movements are most likely due to quality premium factors.

Second, a plausible reason for the inverse price difference between A and X grade coffee may simply be the fact that higher proportions of A, relative to X, grade coffee are produced and exported given favourable
agronomic conditions. Generally, exporters selling their own estate brands of A and X grade coffee receive higher prices, but the average prices between A and X grade coffee received by exporters may vary considerably within a given price range (World Bank 1992, Annex 2, pp. 8-9). Indeed, Fleming and Antony (1993, p. 131) observed that the range of average prices received by different exporters for X grade coffee alone varies by almost a factor of three, compared with the narrow range of average prices received for A grade coffee and the small differences between prices of higher quality X grade and A grade coffee. The implication is that the bulk of X grade produced and exported is lower-quality estate coffee. The average price received for X grade is supported by exports of some higher-quality X grade coffee from estate exporters who also produce much of the A grade coffee.

The inverse relationship between A and X grade coffee may be explained by the fact that when favourable agronomic conditions exist, some of the higher X grade coffee is re-classified and sold by exporters as A grade. As a result of this 'drafting procedure', the higher quality X grade would receive prices comparable to those of average A grade coffee given the relatively low price band for A grade (Fleming and Antony 1993). As a consequence, the overall average price of A grade coffee would rise because of overall quality improvements and the average price of X grade would decline. Due to the high costs of processing lower quality X grade into standards acceptable for higher X grade prices, or even inclusion into A grade coffee, estates producing low-quality X grade are prevented from benefiting from quality improvements because of sub-standard processing methods, even though seasonal factors may be favourable. Because virtually no substitution relationship exists between estate and smallholder coffee, higher-quality Y grade coffee produced as a result of favourable seasonal conditions cannot be re-classified and sold as X grade to support average X grade prices. As a result of these factors, the inverse relationship between A and X grade coffee appears to be consistent with actual occurrences in the PNG coffee market.

A plausible explanation of the positive relationship between A and Y grade coffee in the domestic price system is again the quality premium effect, although in a different direction. The two grades are not substitutes for each other in supply. When favourable agronomic conditions exist in the industry, the quality of both grades of coffee improves and the supply of A and Y grade increases along with their prices. When adverse climatic factors affect the industry, the quality of A and Y grade coffee deteriorates and, as a consequence of this, A and Y grade prices are simultaneously lowered.

As mentioned previously, the results of the second cointegrating vector show the relationship between domestic coffee prices and international market factors. The results reported in Table 4 reveal that long-run relationships between A and X grade prices are insignificant, but an inverse long-run relationship exists between the price series of A and Y grade coffee. This result is most likely a consequence of the relative scarcities of these grades in the world market and the limited degree of substitutability by buyers between the two grades at the margin (Economist Intelligence Unit 1991, p. 57).
A grade coffee and Y grade coffee are very limited substitutes for each other in demand in the sense that the higher quality A grade is used mostly in the production of 'boutique' coffees and the lower quality Y grade is used to produce instant coffee. When global demand and supply factors lead to relative shortages of, say, A grade coffee, competition among roasters requiring higher quality coffee forces up the price of A grade. However, the relative abundance of Y grade stocks causes its price to decline with no compensating effect of inter-grade substitution. The converse situation applies when Y grade coffee is in relatively short supply.

Assuming negligible substitution in demand between A and Y grade coffee and unchanged X grade supply and stocks, the price of A grade coffee would decline if its supply increases, _ceteris paribus_. Such a change could be the result of a transition from the production of Y to A grade coffee by growers attempting to capture the premiums associated with producing higher quality grades. By assuming that A and Y grades are not substitutes in demand, the outward shift in supply by growers normally producing Y grade would result in relative scarcities in the supply of Y grade coffee. This in turn causes the price of Y grade coffee to increase, _ceteris paribus_. The overall impact of these changes, reflecting relative scarcities, is that the long-run prices of A and Y grade coffee move in opposite directions to each other.

The results of the second cointegration test between the domestic price system and the ICO price series (Tables 6, 7 and 8) show that the price system of A, X and Y grade coffee and the OM coffee price system move independently, or drift away from each other. As the PNG coffee industry is a price taker in the world coffee market, the implication is that all PNG grades are being penalised for quality deterioration in the long run. This conclusion is supported by the results presented in Table 8 which report that the coefficients on the OM prices are not significantly different from zero. In other words, no cointegrating relationship exists between OM prices and any of the prices of A, X and Y grade coffee.

There are several factors that might explain the results of the Johansen multivariate test. The result showing that no long-run relationship exists between Y grade and the OM price series was anticipated given that this grade of coffee is produced by smallholders in PNG who generally face capital constraints and are limited in their technical ability; the result is poorly produced and processed coffee. Indeed, the most common complaint levelled at Y grade coffee is excessively high levels of acidity caused by poor processing techniques. The prices of Y grade coffee have nearly always been discounted or penalised against the ICO price, and the result was expected as smallholders in PNG appear to have lost ground over time in the production and processing of bulk OM coffee compared with their international rivals.

The inability of the Johansen test procedure to detect a long-run relationship between the prices of OM and X grade coffee confirms a long-held suspicion by people in the coffee industry that a large proportion of low-quality X grade coffee is being exported, for three reasons. First, given the prevalence of the substitution effect between A and X grade coffee, the costs associated with processing average to good quality X grade beans or, even more difficult, attempting to re-classify and export them as A grade coffee, are prohibitive. Second,
higher quality Y grade coffee cannot be regraded as X grade. Third, the decline in performance of blockholdings since their emergence in the late 1970s (around the beginning of the study period) has meant less good-quality X grade coffee supplied from this sector.

Table 8 also shows that the series of A grade and OM prices do not have a stable, long-run relationship, and drift together over time. This implies that the premium traditionally received for the premier coffee produced in PNG against the ICO indicator price is being progressively eroded over time, because of quality deterioration. This long-term quality deterioration could be caused by law and order difficulties which have been a problem for some time in the estate sector, indeed, the whole coffee industry. According to Fleming and Antony (1993, p. 40), there are broadly four dimensions of the law and order problem; lawlessness, clan warfare, coffee stealing, and unethical and illegal behaviour in business activities. Of these, lawlessness is perhaps the most significant factor causing the quality of A grade coffee to deteriorate in the long term. In general, as law and order conditions have worsened, many highly qualified and experienced managers have been driven out of the coffee industry, taking with them invaluable knowledge and experience gained over many years.

The divergence between A grade and OM prices in the long run may also be attributed to the fact that the indicator price is open to manipulation by vested interest groups (Economist Intelligence Unit 1991, p. 57). In the international market, the ICO categorises coffee as Colombian milds, OM, Brazilian or Other arabicas and robustas which, to some extent, are partial substitutes for one another. The Economist Intelligence Unit (1991, p. 57) reported that a group of South American growers, Pancafé, attempted to raise the price of OM coffee by lifting the price of robusta. As OM and robusta coffees are limited substitutes, the higher prices of robusta would subsequently raise the price for OM coffee. In relation to the test result, therefore, the long-run divergence between the price series of A grade and OM coffees might not be caused solely by quality differences. The main limitation of this argument, however, is that these manipulations tend to have a short-term impact, and cannot be sustained in the long term.

The absence of a long-run relationship between A grade and the OM price could be also be due to the fact that the OM price reflects not only the relative availability of high quality A grade coffee in the OM category but also price expectations of countries producing the other three groups of coffee mentioned above (Economist Intelligence Unit 1991, p. 57). Price-setting nations such as Brazil and Colombia use the indicator price of OMs to determine the prices of their domestic coffees. As a consequence, relative supply imbalances in the other categories of coffee are reflected in the OM price. The absence of any long-term relationship between A grade coffee and the ICO indicator price might be due not to a decline in the quality of A grade coffee but exogenous factors having an impact on the OM price causing it to deviate from the long-run price series of A grade coffee. Also, because there exist two coffee markets (the physical market where quantities of coffee are actually traded and the futures markets indicating short-term availabilities of coffee), the OM price not only reflects imbalances in the supply of high quality coffee but also future expectations of supply and demand.
Consequently, the long-run divergence between the prices of A grade and OM coffee prices may be a result of these factors rather than purely the deterioration of A grade quality. Again, however, there must be some doubt about the persistence of these factors in the long term.

Conclusions

This study was conducted with two objectives in mind. The first objective was to determine the effect of quality on the price system of A, X and Y grade prices. Second, the significance of the world price of OM coffee to domestic price formulation was to be ascertained. The rationale for examining these issues was that many commentators, including the CIC, believe that coffee quality has not only contributed to depressed coffee prices but has perhaps damaged the reputation of PNG as a producer of high quality coffee. To determine the validity of these suppositions, cointegration analysis was undertaken to conduct two tests: first on the domestic price system of A, X and Y grade coffee only, and, second, on the prices of A, X and Y grade coffee and the OM price.

Empirical results for the first test reveal two cointegrating relationships for A, X and Y grade prices. The first vector was attributed to long-run relationships in the domestic price system and the second to the influence of international variables on the long-run prices of A, X and Y grade coffee. The second cointegration test also yielded two vectors and indicated that, in the long run, the OM indicator price was not in a steady-state equilibrium with the prices of A, X and Y grade coffee.

The implications of the first test results are that the concerns held by the CIC and others over deteriorating coffee quality appear warranted. On the basis of these results, it may be seen that coffee quality does have a significant long-run effect on differences in price levels between domestic grades of coffee. The results of the second test imply that the price series of A, X and Y grade coffee and the indicator price deviate from one another in the long run. This, in itself, does not mean that the indicator price has no effect on the prices received by PNG coffee producers; rather, the indications are that the prices for all grades exported are penalised. For all domestic grades of coffee, the most likely explanation is quality deterioration. However, in the case of prices received for A grade coffee, the divergence may also be due to dynamic factors exogenous to the domestic price system which are influencing the OM indicator price.

The results lend support for greater attention to quality deterioration and policies that may improve coffee quality. At the same time it should be stressed that they do not, in themselves, prove there is a need to arrest quality deterioration of PNG coffee exports on economic grounds. Quality deterioration in the PNG coffee industry has been a controversial issue for many years. Numerous recommendations (e.g., prohibiting the sale of cherry coffee) have been made and actions taken in the past to improve quality, but they have largely been ineffective. With the recent collapse of PNG coffee prices, policy measures aimed at arresting quality deterioration have been pursued with renewed vigour.
A major source of contention is the role of the CIC in improving coffee quality which relates primarily to commercial decisions. The assumption held by the CIC that improvements in the quality of PNG coffee are good for the industry may not be valid for two main reasons. First, the potential returns from improving quality are uncertain. Second, the attainment of high quality coffee is not always the most economic solution. The danger here is that by attempting to improve the overall quality of PNG coffee, supply of Y grade, in particular, could be adversely affected. This is not to say that a policy to improve quality should not be pursued; rather, that it be undertaken after careful consideration to the likely financial and economic impact of policy actions.

References


Charemza, W.W. and Deadman, D.F. (1992), New Directions in Econometric Practice: General to Specific Modelling, Cointegration and Vector Autoregression, Edward Elgar, Aldershot.


Dick, G. (1976), The Hagen Coffee Grower (1976), Department of Primary Industry, Port Moresby.


TABLE 1

*Description of Statistical Tests, Variables and Coefficients*

<table>
<thead>
<tr>
<th>Statistical tests</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>Augmented Dickey-Fuller test for a unit root</td>
</tr>
<tr>
<td>PP</td>
<td>Phillip-Perron test for a unit root</td>
</tr>
<tr>
<td>LR₁</td>
<td>likelihood ratio to determine the lag length in the system</td>
</tr>
<tr>
<td>Trace test</td>
<td>test for the rank of the Π matrix</td>
</tr>
<tr>
<td>FTR</td>
<td>Fail to reject hypothesis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A grade coffee</td>
</tr>
<tr>
<td>X</td>
<td>X grade coffee</td>
</tr>
<tr>
<td>Y</td>
<td>Y grade coffee</td>
</tr>
<tr>
<td>OM</td>
<td>ICO indicator price for OM coffee</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>α&lt;sub&gt;ij&lt;/sub&gt;</td>
<td>Weight of cointegration term in the ECM (i = 1 for A, 2 for X, 3 for Y and 4 for OM; j = 1 for first weight, 2 for second)</td>
</tr>
<tr>
<td>β&lt;sub&gt;ij&lt;/sub&gt;</td>
<td>Cointegrating coefficient (i = 1 for first cointegrating vector; j = 2 for the second; i = 1 for A, 2 for X, 3 for Y grade and 4 for OM)</td>
</tr>
</tbody>
</table>

TABLE 2

*Likelihood Ratio Test to Determine the Lag Length of Each Equation in the System for A, X and Y Coffee Prices*

<table>
<thead>
<tr>
<th>Ho:</th>
<th>LR₁ (p-value)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>k = 2</td>
<td>32.9836 (0.0001)</td>
<td>Reject</td>
</tr>
<tr>
<td>k = 3</td>
<td>9.6707 (0.3778)</td>
<td>FTR</td>
</tr>
</tbody>
</table>
TABLE 3

<table>
<thead>
<tr>
<th>Hypothesis on rank (H)</th>
<th>Trace test</th>
<th>Critical values** (95%)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (r ≤ 1)</td>
<td>82.65</td>
<td>35.068</td>
<td>Reject</td>
</tr>
<tr>
<td>1 (r ≤ 2)</td>
<td>39.98</td>
<td>20.168</td>
<td>Reject</td>
</tr>
<tr>
<td>2 (r ≤ 3)</td>
<td>4.10</td>
<td>9.094</td>
<td>FTR</td>
</tr>
</tbody>
</table>

TABLE 4

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_{11}$</td>
<td>-0.211</td>
<td>$\beta_{10}$</td>
<td>-0.204</td>
</tr>
<tr>
<td>$\alpha_{12}$</td>
<td>-0.375</td>
<td>$\beta_{11}$</td>
<td>1</td>
</tr>
<tr>
<td>$\alpha_{21}$</td>
<td>0.251</td>
<td>$\beta_{12}$</td>
<td>-1.606</td>
</tr>
<tr>
<td>$\beta_{13}$</td>
<td>0.655</td>
<td>$\beta_{20}$</td>
<td>-0.731</td>
</tr>
<tr>
<td>$\alpha_{22}$</td>
<td>-0.161</td>
<td>$\beta_{21}$</td>
<td>1</td>
</tr>
<tr>
<td>$\alpha_{31}$</td>
<td>-0.162</td>
<td>$\beta_{22}$</td>
<td>0.131</td>
</tr>
<tr>
<td>$\alpha_{32}$</td>
<td>0.168</td>
<td>$\beta_{23}$</td>
<td>-1.010</td>
</tr>
</tbody>
</table>

Note: Order of ECM = 3, $\beta_{10}$ and $\beta_{20}$ are constants.

TABLE 5

<table>
<thead>
<tr>
<th>Ho:</th>
<th>LR$_{1}$ (p-value)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>k = 3</td>
<td>33.5396 (0.0063)</td>
<td>Reject</td>
</tr>
<tr>
<td>k = 4</td>
<td>19.2912 (0.2538)</td>
<td>FTR</td>
</tr>
</tbody>
</table>
### TABLE 6

*Johansen Cointegration Test Results for A, X, Y and OM Grade Coffee Prices*

<table>
<thead>
<tr>
<th>Hypothesis on rank (Π)</th>
<th>Trace test</th>
<th>Critical values** (95%)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (r &lt; 1)</td>
<td>95.24</td>
<td>53.347</td>
<td>Reject</td>
</tr>
<tr>
<td>1 (r &lt; 2)</td>
<td>46.10</td>
<td>35.068</td>
<td>Reject</td>
</tr>
<tr>
<td>2 (r &lt; 3)</td>
<td>16.18</td>
<td>20.168</td>
<td>FTR</td>
</tr>
<tr>
<td>3 (r &lt; 4)</td>
<td>5.97</td>
<td>9.094</td>
<td>--</td>
</tr>
</tbody>
</table>

**Note:** Order of ECM=4, \( \beta_{10} \) and \( \beta_{20} \) are constants.

### TABLE 7

*Estimates of Cointegrating Relationships and Weights by the Johansen Maximum Likelihood Test for the Prices of A, X, Y and OM Grade Coffee*

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_{11} )</td>
<td>-0.181</td>
<td>( \beta_{10} )</td>
<td>0.211</td>
</tr>
<tr>
<td>( \alpha_{12} )</td>
<td>-0.297</td>
<td>( \beta_{11} )</td>
<td>1</td>
</tr>
<tr>
<td>( \alpha_{21} )</td>
<td>0.332</td>
<td>( \beta_{12} )</td>
<td>-1.710</td>
</tr>
<tr>
<td>( \alpha_{22} )</td>
<td>-0.096</td>
<td>( \beta_{13} )</td>
<td>0.838</td>
</tr>
<tr>
<td>( \alpha_{31} )</td>
<td>-0.109</td>
<td>( \beta_{14} )</td>
<td>-0.148</td>
</tr>
<tr>
<td>( \alpha_{32} )</td>
<td>0.269</td>
<td>( \beta_{20} )</td>
<td>-1.038</td>
</tr>
<tr>
<td>( \alpha_{41} )</td>
<td>-0.071</td>
<td>( \beta_{21} )</td>
<td>1</td>
</tr>
<tr>
<td>( \alpha_{42} )</td>
<td>-0.085</td>
<td>( \beta_{22} )</td>
<td>0.113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \beta_{23} )</td>
<td>-1.036</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \beta_{24} )</td>
<td>0.100</td>
</tr>
</tbody>
</table>
TABLE 8

*Likelihood Ratio Test for the Hypothesis that the OM Price Does Not Belong in the Cointegrating Relationship*

<table>
<thead>
<tr>
<th>Null hypothesis</th>
<th>Likelihood ratio test</th>
<th>p-value</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta' = \begin{bmatrix} 1 &amp; -\beta_{22} &amp; -\beta_{23} &amp; 0 &amp; \beta_{10} \ 1 &amp; -\beta_{22} &amp; -\beta_{23} &amp; 0 &amp; \beta_{20} \end{bmatrix} )</td>
<td>( \beta_{14} = 0 ) and ( \beta_{24} = 0 )</td>
<td>2.62</td>
<td>0.27</td>
</tr>
</tbody>
</table>
1 Glossop (1984, pp. 1-3) stated that the quality of green coffee beans is determined on the basis of bean uniformity and shape, number of defects, moisture content (colour), density and odour.

2 A grade coffee is the major high-quality coffee exported, followed by X grade. Both of these grades are predominantly produced by estates and blockholdings. Y grade is the lowest quality of the three main grades, and its export is mainly by smallholders.

3 Readers interested in the historical aspects of PNG coffee production are referred to Cartledge (1978) for a detailed analysis.

4 Readers interested in a detailed explanation of the procedure are referred to Johansen (1988) and Johansen and Juselius (1990).

5 Interested readers are referred to Enders (1995, pp. 385-400) for a detailed explanation and illustration of the method.

6 The prices of A, X and Y grade coffee in PNG and the ICO indicator price for OM are recorded in toea per kilogram. One Kina comprises 100 toea.

7 The implication here is that international transfer charges remained constant in real terms over the study period. This is considered a fairly robust assumption to make.

8 The results of the ADF and PP unit roots test conducted on the price series of A, X, Y and OM coffee are not presented here, but are available upon request. They indicate the presence of a unit root in each of the series. Due to the nature of the industry, an assumption was made concerning the presence of autocorrelation in the model. The order of the ECM decided on was $k = 3$. The estimated residuals showed no sign of autocorrelation.

9 The magnitudes of these relationships were not ascertained due to the characteristics of the testing procedures.


A Note on A Bayesian Estimator in an Autocorrelated Error Model. William Griffiths and Dan Dao, No. 3 - April 1979.


Bayesian Econometrics and How to Get Rid of Those Wrong Signs. William E. Griffiths, No. 31 - November 1987.


A Comparison of Alternative Functional Forms for the Lorenz Curve.
Duangkamon Chotikapanich, No. 60 - October 1991.

A Disequilibrium Model of the Australian Manufacturing Sector.

Overnight Money-Market Interest Rates, The Term Structure and The


Estimation of Stochastic Frontier Production Functions with Time-Varying
Parameters and Technical Efficiencies Using Panel Data from Indian

The Demand for Australian Wool: A Simultaneous Equations Model Which Permits

A Stochastic Frontier Production Function Incorporating Flexible Risk

Income Inequality in Asia, 1960-1985: A Decomposition Analysis.

A MIMIC Approach to the Estimation of the Supply and Demand for Construction
Materials in the U.S. Alicia N. Rambaldi, R. Carter Hill and

A Stochastic Frontier Production Function Incorporating A Model For Technical
Inefficiency Effects. G.E. Battese and T.J. Coelli, No. 69 -
October 1993.

Finite Sample Properties of Stochastic Frontier Estimators and Associated

Measurement of Total Factor Productivity Growth and Biases in Technological
Change in Western Australian Agriculture. Tim J. Coelli, No. 71 -
December, 1993.

An Investigation of Stochastic Frontier Production Functions Involving Farmer
Characteristics Using FCR31AT Data From Three Indian Villages.

A Monte Carlo Analysis of Alternative Estimators of the Tobit Model.
Getachew Asgedom Tessema, No. 73 - April, 1994.

A Bayesian Estimator of the Linear Regression Model with an Uncertain
Inequality Constraint. W.E. Griffiths and A.T.K. Wan, No. 74 -

Predicting the Severity of Motor Vehicle Accident Injuries Using Models of
Ordered Multiple Choice. C.J. O'Donnell and D.H. Connor, No. 75 -
September, 1994.


