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Price Transmission in the Papua New Guinea Coffee Market: A Vector Autoregression Approach

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Abstract

The coffee sector plays a key role to the Papua New Guinea (PNG) economy, employing over 30 per cent of the population. Crucially, the sector is dominated by smallholder farmers that contribute to more than three-quarters of the country's total coffee production. Almost all the coffee produced is exported, mainly to countries like Australia, Germany, the United Kingdom and the United States. In recent periods the coffee sector has been struggling, with production reported to be in a steady decline. One the major reasons for this is thought to be poor price transmission from world markets to farmers. In this study, a Vector Error Correction model is used to assess the price transmission between world markets and PNG's exporters, processors and farmers. Past studies have also analysed the same issue, though relying on different methodologies. The methodology used here can be regarded as an intermediate approach between the previous studies. The same monthly datasets used in past studies, covering the period January 1999 and December 2017, were used here. Although the results reported here essentially corroborate those found in previous studies, two main differences can be highlighted. First, evidence was found in favour of price transmission from world markets to exporters. Due to market integration between exporters and processors and farmers, such price transmission from world markets is also spread through to the upstream actors in the coffee supply chain in PNG. Second, the results point to exporters as the main agents practicing price levelling domestically. That can be perceived as a strategy from exporters to remain competitive in the global coffee market.

Keywords: PNG, coffee, price transmission, VEC

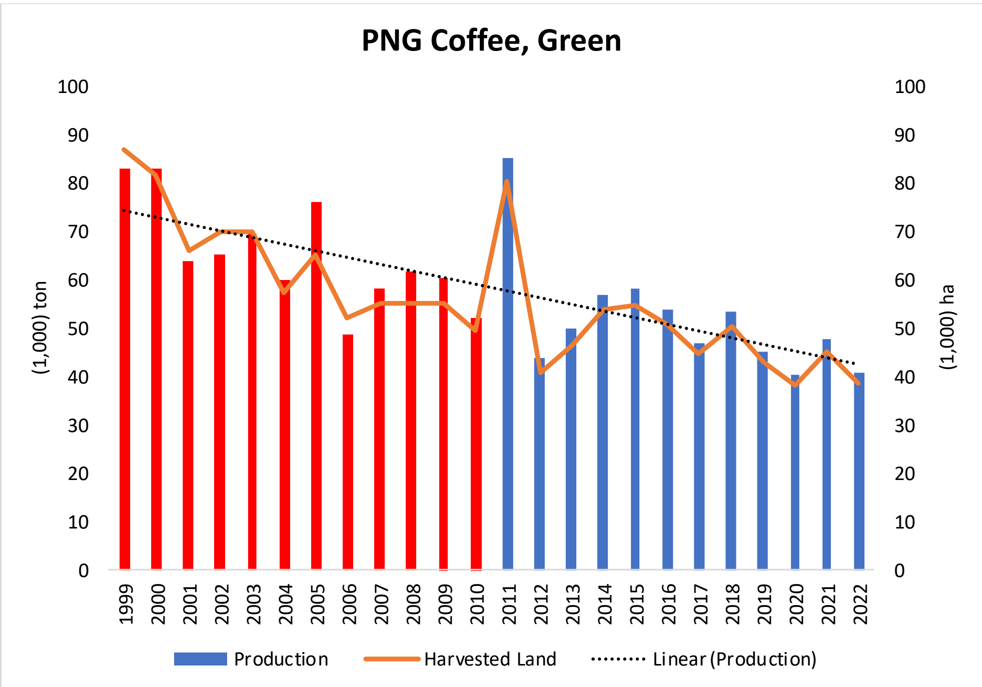
Introduction

Coffee is amongst the most important agricultural commodities in Papua New Guinea (PNG). It has been cultivated since the 1800s (West, 2011), and in recent years the country has been ranked in the top 20 producers of coffee (Nakatani, 2018). Domestically, the industry employs directly and indirectly more than 30 per cent of the population (West, 2011).

The coffee industry in PNG is dominated by the smallholder sector, which is responsible for over 75 per cent of domestic production (West, 2011). This sector is described as "small family-owned and operated coffee gardens with little to no support from private or government agricultural extension", and reliant on coffee as their major source of income (West, 2011, p. 236). The integrated processor-exporter plantations and the larger commercial farmers produce less than 25 per cent of output. Almost all the coffee produced in PNG is exported, mainly to Australia, Germany, the United Kingdom and the United States (West, 2011).

A number of studies (Imbun, 2014; McKillop & Wood, 2010) have noted that the PNG coffee industry has been in a steady decline for many years. More recent reviews have confirmed this situation (Anon, 2018; Sengere, Curry, & Koczberski, 2019). This is also evidenced in Figure 1 below. The main reason has been linked to the low prices for farmers (although the supply response to the price peak in 2010/11 is clearly evident). As shown in Figure 2, there are periods in which prices at the farm level are less than half of the price received by PNG exporters in the world market. As a reaction to that, farmers' interest in coffee as a cash crop has waned and production has been declining (McKillop & Wood, 2010). Accordingly, McKillop and Wood (2010) reported that around 60 per cent of the coffee exported by PNG is of Y grade or lower, i.e., coffee of fairly average quality (Imbun, 2014). This proportion has increased in the last decade (Anon, 2018). This coffee almost always comes from smallholders.

Figure 1. PNG coffee production and harvested land area (1999-2022)



Source: Data from FAO (2024)

Many studies have pointed out the challenges facing the PNG coffee industry, while some have suggested interventions that are necessary to revitalise the sector. These include the establishment of partnerships between farmers' groups and key leaders in the value chain (e.g., input, credit, freight service providers and others) (Sengere et al., 2019), improvements in infrastructure to facilitate trade and the more widespread provision of agricultural extension services (McKillop & Wood, 2010), as well as improvements in the overall business environment (Imbun, 2014). Whilst some of these may seem straightforward interventions, other supply chain inefficiencies that interfere with the transmission of price movements caused by world market price volatility back to farmers are little mentioned. Poor price transmission may prevent farmers from making best-informed production and marketing decisions and could pose a threat to the long-term sustainability of the coffee industry in the country. For example, in Figure 2 it is clear that the margin between the prices in world markets (New York futures prices, and FOB export prices) and the prices received by farmers (FDR) expands when price levels are high and contracts when prices are at lower levels. This is evidence of price levelling by the exporter and processor stages of the coffee value chain.

The question is "what is the best way to analyse the coffee industry for price transmission efficiency?" Two recent studies have taken opposite paths to address this issue. Griffith et al. (2023) adapted a traditional price levelling approach (Parish, 1967) to the case where price variability comes from the demand side of the market, as in the highly export-dependent PNG coffee industry. In these models, linearity and equilibrium behaviour is assumed, so standard causality models can be specified and estimated. The authors found that, at the whole chain level, short-run price levelling was confirmed and both aggregate costs and total volume of exports were significant determinants of the size of the margin. Short-run price levelling was also confirmed at both the exporting and processing stages, but in the preferred models, while throughput was an important determinant of exporter and processing margins, costs had a significant but negative effect on margins. Partial adjustment processes were also found to be important in determining margins at all stages, but inclusion of such variables masks a lot of detail about the dynamics.

Huffaker et al. (2021) did not assume linearity or market stability but tested for them using new empirical methods incorporating nonlinear time series analysis and recently-emerging causal-detection methods from empirical nonlinear dynamics. The reason for selecting this approach was the research available which indicated cycles of different periodicity in global coffee production and price data. The authors found empirical evidence of price transmission from the global market to domestic exporters and processors, but not through to producers. In particular, the differential between the world price and the FOB price switched from negative to positive when prices were falling compared to when they were rising. Thus, as above, this is a strong indication of price levelling behaviour by coffee exporters.

Lying between these extremes are the vector autoregression (VAR) approaches, which are generalisations of the univariate autoregressive model for forecasting a time series. They assume equilibrium behaviour and reversion to stability following a shock in the system, and allow cointegration and Granger-causality testing of behaviour. Variants include an error correction model form. While the nonlinear dynamics approach cannot be faulted if the test results indicate the need for that approach, it is a highly complex process which requires very specialised knowledge and specialised programming ability. If the same implications are drawn from the different modelling approaches, does the simpler approach provide results that are "close enough"?

The aim of this study is to assess the domestic and world market price transmission for coffee in PNG using a VAR model and the same data set as used in the two previous published analyses (Huffaker et al., 2021; Griffith et al., 2023)[1]. The major proposition of this study is that a lack of market integration, measured through price transmission in a VAR model, can be shown. This would confirm the previous analyses that poor price transmission is one of the major reasons for the lack of productivity in the PNG coffee industry, especially at the farm level.

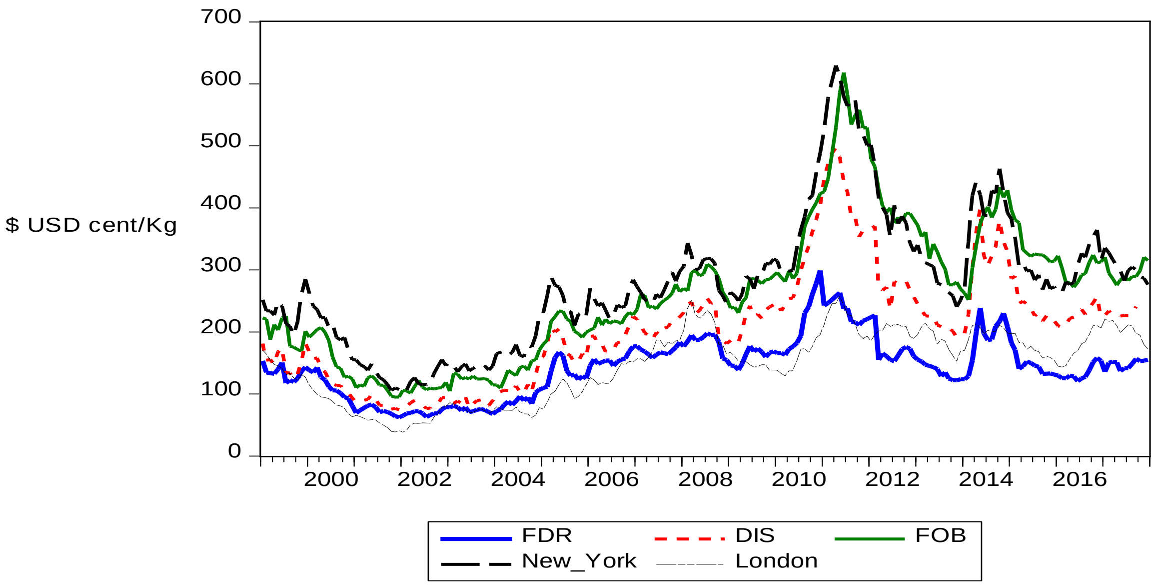
Data

The analyses are based on monthly data from January 1999 to December 2017, collected from the PNG's Coffee Industry Corporation (CIC). This data set has been described in detail in the previous analyses (Dambui et al., 2015; Huffaker et al., 2021; Griffith et al., 2023). The dataset covers domestic

[1] Although the Griffith et al. (2023) study was only for the period 1999-2010 due to constraints with the cost data used.

prices at different market levels as well as prices from world markets (New York and London futures market prices). Domestic prices include a factory-door price (FDR), which is the price offered to PNG farmers; a delivered-in-store price (DIS), which is the price paid to processors by exporters; and a free-on-board price (FOB), which is the export price for each shipment reported by the CIC. FOB prices are based on New York futures market prices, with a premium or discount according to the coffee grade.

Figure 2. Nominal coffee prices in PNG and world markets (1999-2017)



Source: CIC database

In Figure 2 is shown the nominal coffee price over the period January 1999 to December 2017 for each of the market levels in PNG described above as well as in world markets. In general, the prices appear to be closely related, more so prior to 2010. As well, there are two distinct phases describing the data over this time period - a phase of increasing prices between 2002 and 2011, and then a downward trend in prices from the peak in 2011 to 2017[2]. Apart from the price spike, overall the price trends rather resemble a "random walk" process as described in econometrics textbooks; i.e., appearing to wander upward and downward without a clear pattern over time (Hill, Griffiths & Lim, 2011).

Across the whole period, variability has been high for all price series as shown by the coefficient of variation (CV) in Table 1, although the price paid to farmers is the least variable over this time period.

Table 1. Descriptive statistics of nominal prices (N = 225) (US c/kg)

	FDR	DIS	FOB	NEW YORK	LONDON
Mean	143.65	205.41	260.91	278.12	145.96
Maximum	299.11	496.62	618.24	629.70	257.46
Minimum	62.51	74.27	94.70	106.04	38.43
Std. Dev.	48.77	91.54	112.23	109.08	57.09
CV	0.34	0.45	0.43	0.39	0.39

[2] The price spike in 2011 was attributed in industry reports at the time (Agritrade, 2011) to be due to supply problems in major South American producers such as Colombia due to weather events, the lowest level of stocks of beans since the 1960s, increased demand for single-origin coffee beans, and also by speculative investments (which were said to be unlikely to be sustained). The record shows that this was indeed the case.

For the econometric analysis, all price series were adjusted to real terms using the US CPI[3] collected from the International Monetary Fund (IMF, 2020), and used in log-form.

Method

Vector autoregressive modelling approaches are probably the most-used techniques to assess price transmission (see also Li et al., 2013). As noted above, this modelling approach assumes a linear relationship in price transmission.

To implement a VAR model, two choices have to be made prior to estimation. One is related to the lag order for the regressors, that is the number of past lagged values which influence the current value. The other is related to the variable form. This is dependent on the variables' stationarity and cointegration conditions. These two conditions determine whether a VAR model is estimated in levels, first differences or with an error-correction term (i.e., a VEC model). Results from the pre-estimation tests suggested a lag order of two (the starred values on the LR test and three of the four information criteria in Appendix Table 1); and evidence of non-stationarity for all the coffee price variables (the bolded MacKinnon p values in Appendix Table 2 are all 0.20 or higher).

Based on the outcomes from the pre-estimation, a structural vector error-correction (VEC) model was used. The equation below describes the VEC model estimated in this study, with a lag order of two. The analyses also include Granger causality tests and descriptive statistics.

$$\Delta x_t = \pi_0 + \pi x_{t-1} + \sum_{i=1}^{p-1} \pi_i \Delta x_{t-i} + \sum_{j=1}^{J} B_j Z_{j,t} + \varepsilon_t$$

Where:

p = the chosen lag length;
x_t = *(n x 1)* vector of endogenous variables (domestic coffee price series) at time *t*;
Δx_{t-i} = *(n x 1)* vector of x_{t-i} in first differences;
π = matrix rank;
π_0 = *(n x 1)* vector of intercepts;
B = *(J x J)* vector of the parameters for the dummy regressors;
Z_t = *(J x J)* matrices of dummy variables (t = 1, 2… 11; from January to November);
ε_t = *(n x 1)* vector of the white-noise disturbance term.

Results

Results from the VEC model indicate the presence of one cointegrating vector in the system (Appendix Table 5). Under a such condition, it can be inferred that a long run relationship exists across the different coffee prices analysed. Full results from the estimated VEC model are split between Tables 2 and 3.[4]

[3] CPI for PNG covering the whole period of the dataset could not be assessed, therefore, the US CPI was used.

[4] The estimated model satisfies the autocorrelation and heteroskedasticity assumptions and, as such, remains statistically valid. The results from these specification tests are shown in Appendix Table 3 (the calculated LM statistics indicate no autocorrelation at any lag length) and Appendix Table 4 (the joint Chi-sq statistic shows no heteroskedasticity, the individual Chi-sq statistics confirm, and only two of the calculated F statistics show significant results), respectively.

In Table 2 are displayed the results from the error correction component of the VEC model and the consequent estimated short-run parameters. The error correction term parameters are also called the speed of adjustment parameters. They indicate the speed at which each variable responds to a deviation from the long-run equilibrium in previous periods (as determined by the lag length tests shown in Appendix Table 1). The results show that only FOB prices adjust from the previous two months' deviation and at a rate of 9.8 per cent towards the equilibrium condition. Such shocks are also caused by price changes both at FDR (farm) and DIS (processing) levels as the short-run parameters for the FOB equation suggest. The other prices do not adjust from their previous period deviations, given the non-significance of their speed of adjustment parameters. The fact that at least one of the speed of adjustment coefficients is significant justifies the appropriateness of a VEC formulation over a standard VAR model to analyse this problem (Enders, 2014).

Table 2. VEC short run parameters

	ΔFDR	ΔDIS	ΔFOB	ΔNY	ΔLON
Speed of adjustment	-0.0076	0.036	-0.098***	0.021	0.0080
ΔFDR(-1)	-0.11	0.28	0.20***	-0.045	0.048
ΔFDR(-2)	-0.066	-0.044	0.13*	-0.023	0.042
ΔDIS(-1)	-0.18	-0.44***	-0.31***	-0.16	-0.18
ΔDIS(-2)	0.094	0.10	-0.19**	0.089	-0.068
ΔFOB(-1)	0.16*	0.10	-0.12*	0.073	0.012
ΔFOB(-2)	0.023	-0.014	-0.026	0.079	0.16**
ΔNY(-1)	0.65***	0.84***	0.38***	0.28**	0.13
ΔNY(-2)	0.058	0.19	0.27***	0.11	0.085
ΔLON(-1)	0.070	-0.0065	-0.018	0.16	0.34***
ΔLON(-2)	-0.033	-0.10	-0.13*	-0.12	-0.047

These results suggest that shocks in FOB prices cause the reductions in them over time, which occurs irrespective of changes in other (domestic and international) price levels. The interpretation of that is threefold. The first interpretation, as expected, is that PNG is a price taker in the global coffee market; and, as such, international prices do not respond to disequilibria in PNG domestic prices. Secondly, the negative sign for FOB prices signals that any own price shocks in the current period will cause FOB prices to decline relatively rapidly in the next period, towards the equilibrium. This reinforces PNG's small position in the global coffee market, whose main form of competition is through price reduction. Lastly, it also corroborates the findings from past studies, which suggest that processors and exporters practice price levelling (Griffith et al., 2023). Accordingly, the findings suggest that shocks causing price fluctuation in downstream coffee supply chain levels (exporters) are not rapidly transmitted upstream (to processors and farmers). Hence, up to this point, some evidence exists that exporters, at least, adopt price levelling.

In Table 3 are reported coefficients that explain the long-run relationships across the coffee market levels. Just one such set of relationships is evident based on the rank order selection tests reported in Appendix Table 5. These coefficients are reported for different normalised equations, so that long-term causality can be interpreted for each of the segments analysed. The magnitude of the coefficients reported is apparently very high, which makes its quantitative interpretation trivial. Yet, their significance and direction seem very revealing for a couple of reasons. Firstly, it confirms that there is a positive and significant long-run relationship between FDR and DIS. It is highlighted in Griffith et al. (2023) that there is a high degree of vertical coordination between these two supply chain segments in PNG, through the existing contractual agreements between "almost all" producers and processors. Secondly, the fact that about one-third of PNG coffee plantations are vertically integrated through to the export sector, corresponding to about 57 per cent of exports (Griffith et al., 2023), can also explain the positive long-run relationship between DIS and FOB prices. The negative relationship between FOB and FDR prices (and, hence, NY and FDR), however, can partially be justified by the equilibrium restoration condition; which means long-run price levelling.

Table 3. VEC long run and speed of adjustment parameters

	Equation				
	FDR	DIS	FOB	NY	LON
	Long run parameters				
β_{FDR}	1	0.28***	-0.31***	3.67***	6.82***
β_{DIS}	3.52***	1	1.08***	-12.91***	-24.01***
β_{FOB}	-3.26***	0.93***	1	11.96***	22.24***
β_{NY}	0.27	-0.077	0.084	1	-1.86
β_{LON}	0.15	-0.042	0.045	-0.54	1

Huffaker et. al (2021) found price transmission relationships from global coffee markets to PNG's export (FOB) and processing (DIS) segments, and domestically between exporters and processing. The results reported in Table 3 also point to existing long-run relationships between world market prices and PNG prices in the three segments (exporters, processors and farmers). Yet, the negative relationships found between exporters (FOB) and farmers (FDR) – or world markets (NY and LON) and processors (DIS) – can also be justified on the basis of indirect market integration that characterises all the supply chain segments. As such, with price levelling being implemented by exporters, resulting in the negative relationship between FOB and FDR after accounting for the lagged reactions, the indirect relationship between world markets and processors is expected to mimic of the previous stage (FOB and FDR). Such an indirect relationship is also expected to cause the complete market integration that is not captured in Huffaker et. al (2021) analysis. As pointed out by Fackler and Goodwin (2001), markets not trading directly with each other can still be integrated if they share a common market that trades with each of them. This concept seems to fit quite well in this coffee market context. World markets and PNG processors do not trade together directly but are indirectly linked through exporters. The same can also be explained for exporters and farmers, that are more likely to be indirectly linked through processors.

Results from the VEC model are also supported by Granger causality test results shown in Table 4. A Granger causality test shows the direction of causality between two variables, which is not necessarily evident from VEC (or VAR) models. Results from this test reveal that all PNG coffee price levels react to changes in prices from the New York market. This is an unsurprising outcome, given the reasonings discussed earlier. It also emphasises the country's position as a price taker in the global coffee market. Similarly, PNG coffee prices are unrelated to changes in prices from the London market, as that market focusses on a different variety of coffee from that grown in PNG.

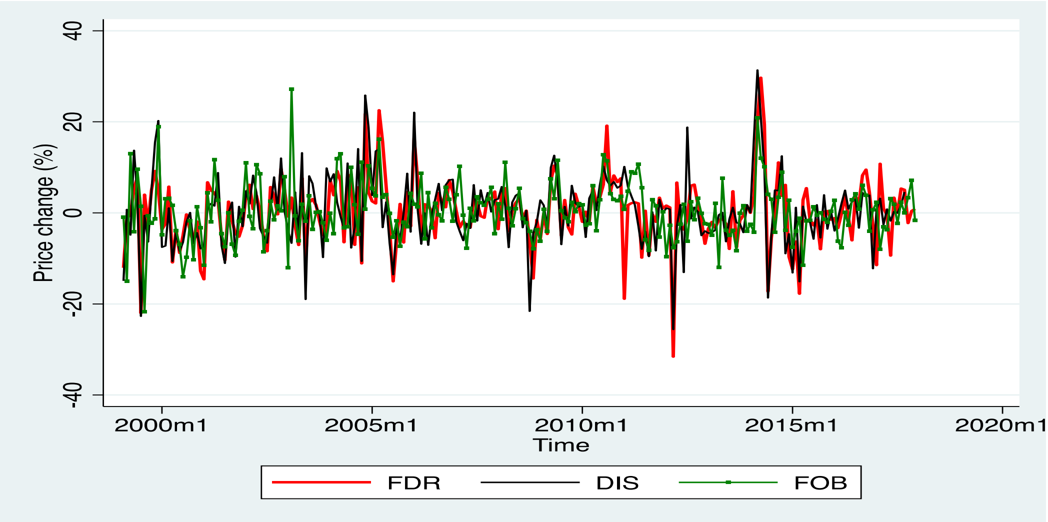
Table 4. Granger causality tests

Variable Granger causes	FDR	DIS	FOB	New York	London
FDR	-	0.8	0.0037***	0.65	0.6
DIS	0.19	-	0.0015***	0.28	0.16
FOB	0.072*	0.3	-	0.43	0.88
New York	<0.0001***	<0.0001***	<0.0001***	-	0.27
London	0.48	0.95	0.8	0.11	-

In addition, results from the Granger causality test indicate that FOB prices are caused by price changes at the upstream end of the value chains. Such a result is consistent with the short-run parameters reported in Table 2. Linking that with the direction and significance of the parameter for the FOB equation, reported in Tables 2 and 3, reinforces the proposition that exporters practice price levelling.

To extend the analyses, annual price changes for each of the coffee supply chain segments in PNG were computed, as shown in Figure 3.

Figure 3. Annual percentage changes in PNG coffee prices (1999-2017)



Annual changes in FOB prices are smaller compared to FDR and DIS prices. That is particularly evident since 2005. The correlation coefficients for these three price levels also support a stronger relationship between DIS and FDR over FOB, and between DIS and FDR (Table 5). Again, these outcomes reinforce the role of exporters in absorbing price shocks deriving from either the domestic or world markets. It can be perceived as a strategy adopted by exporters to ensure they remain competitive in the global market.

Table 5. Correlation coefficients for annual price changes

	Δ% FDR	Δ% DIS	Δ% FOB
Δ% FDR	1.00	-	-
Δ% DIS	0.71	1.00	-
Δ% FOB	0.38	0.28	1.00

Conclusion

In this study the domestic and world market price transmission for coffee in PNG was assessed using a VEC model. The same data set as used in past studies (covering the period January 1999 to December 2017) was relied on, though using a different methodology. Griffith et al. (2023) adopted a marketing margin analysis based on multiple linear regression models and Huffaker et. al (2021) relied on a singular spectrum analysis, which is based on non-linear relationships. Although the results reported here essentially corroborate those found in previous studies, two main differences can be highlighted. First, evidence was found in favor of price transmission from world markets to exporters. Due to market integration between exporters and processors and farmers, such price transmission from world markets is also spread through to the upstream actors in the coffee supply chain in PNG. Second, the results point to exporters as the main agents practicing price levelling domestically. That can be perceived as a strategy from exporters to remain competitive in the global coffee market.

In terms of the modelling approach used, to generate essentially the same types of market implications, the VAR method is much easier to apply. Sophisticated programming skills are not required as in the non-linear dynamics approach, and detailed data on the costs of supplying processing and exporting market services are not required as in the structural econometric approach. Linear VAR models, despite being less sophisticated, still represent an effective tool to capture market price dynamics and relationships.

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Appendix

Appendix Table 1. Lag-order selection criteria

Sample: **1999m9** thru **2017m9** Number of obs = **217**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	557.187				7.0e-09	-4.58237	-4.20486	-3.64784
1	1774.67	2435	25	0.000	1.2e-13	-15.573	-15.0382	-14.2491*
2	1825.9	102.46*	25	0.000	9.4e-14*	-15.8148*	-15.1227*	-14.1015
3	1843.6	35.389	25	0.081	1.0e-13	-15.7474	-14.898	-13.6447
4	1859.68	32.156	25	0.154	1.1e-13	-15.6652	-14.6585	-13.1731
5	1875.35	31.353	25	0.178	1.2e-13	-15.5793	-14.4153	-12.6978
6	1885.84	20.967	25	0.694	1.4e-13	-15.4455	-14.1242	-12.1746
7	1901.29	30.9	25	0.192	1.5e-13	-15.3575	-13.8789	-11.6972
8	1918.17	33.76	25	0.113	1.7e-13	-15.2826	-13.6467	-11.233

* optimal lag
Endogenous: **l_FDR_cpi l_DIS_cpi l_FOB_cpi l_New_York_cpi l_London_cpi**
Exogenous: **dd1 dd2 dd3 dd4 dd5 dd6 dd7 dd8 dd9 dd10 dd11 _cons**

Appendix Table 2. Results from the Augmented-Dickey-Fuller test for stationarity

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Augmented Dickey–Fuller test for unit root

Variable: l_FDR_cpi                         Number of obs  = 225
                                            Number of lags =   2

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test      ──────── critical value ─────────
              statistic           1%           5%          10%
──────────────────────────────────────────────────────────────
 Z(t)            -2.219       -3.468       -2.882       -2.572
──────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.1995.

Augmented Dickey–Fuller test for unit root

Variable: l_DIS_cpi                         Number of obs  = 222
                                            Number of lags =   2

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test      ──────── critical value ─────────
              statistic           1%           5%          10%
──────────────────────────────────────────────────────────────
 Z(t)            -1.902       -3.469       -2.882       -2.572
──────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.3311.

Augmented Dickey–Fuller test for unit root

Variable: l_FOB_cpi                         Number of obs  = 225
                                            Number of lags =   2

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test      ──────── critical value ─────────
              statistic           1%           5%          10%
──────────────────────────────────────────────────────────────
 Z(t)            -1.510       -3.468       -2.882       -2.572
──────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.5286.

Augmented Dickey–Fuller test for unit root

Variable: l_New_York_cpi                    Number of obs  = 225
                                            Number of lags =   2

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test      ──────── critical value ─────────
              statistic           1%           5%          10%
──────────────────────────────────────────────────────────────
 Z(t)            -2.015       -3.468       -2.882       -2.572
──────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.2799.

Augmented Dickey–Fuller test for unit root

Variable: l_London_cpi                      Number of obs  = 225
                                            Number of lags =   2

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test      ──────── critical value ─────────
              statistic           1%           5%          10%
──────────────────────────────────────────────────────────────
 Z(t)            -1.812       -3.468       -2.882       -2.572
──────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.3744.
```

Appendix Table 3. Autocorrelation test

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1999M01 2017M12
Included observations: 222

Lags	LM-Stat	Prob
1	31.46581	0.1741
2	19.94912	0.7495
3	32.25654	0.1507
4	27.84311	0.3151
5	17.61364	0.8583
6	24.06287	0.5157
7	18.22542	0.8327
8	18.91828	0.8010
9	21.65817	0.6554
10	21.63463	0.6567
11	23.14691	0.5690
12	31.48326	0.1735

Probs from chi-square with 25 df.

Appendix Table 4. Heteroskedasticity test

VEC Residual Heteroskedasticity Tests: Includes Cross Terms
Sample: 1999M01 2017M12
Included observations: 222

Joint test:

Chi-sq	df	Prob.
3170.489	3135	0.3246

Individual components:

Dependent	R-squared	F (209,12)	Prob.	Chi-sq (209)	Prob.
res1*res1	0.939256	0.887803	0.6599	208.5149	0.4965
res2*res2	0.917529	0.638786	0.8963	203.6915	0.5906
res3*res3	0.991410	6.627037	0.0004	220.0931	0.2858
res4*res4	0.979594	2.756275	0.0252	217.4699	0.3295
res5*res5	0.925509	0.713369	0.8331	205.4631	0.5562
res2*res1	0.948981	1.067976	0.4885	210.6738	0.4545
res3*res1	0.963675	1.523225	0.2084	213.9359	0.3928
res3*res2	0.943520	0.959160	0.5889	209.4614	0.4780
res4*res1	0.945867	1.003240	0.5468	209.9825	0.4679
res4*res2	0.944762	0.982026	0.5668	209.7373	0.4726
res4*res3	0.946562	1.017028	0.5340	210.1367	0.4649
res5*res1	0.956756	1.270302	0.3366	212.3998	0.4215
res5*res2	0.913751	0.608289	0.9184	202.8528	0.6068
res5*res3	0.918908	0.650618	0.8871	203.9975	0.5847
res5*res4	0.943573	0.960114	0.5879	209.4732	0.4778

Appendix Table 5. Rank order selection tests

Null hypothesis	Trace Test statistic	5% critical value	Max Test statistic	5% critical value
r = 0	96.69**	69.82	56.12**	33.88
r ≤ 1	40.58	47.86	21.33	27.58
r ≤ 2	19.24	29.80	9.97	21.13
r ≤ 3	9.27	15.49	8.09	14.26
r ≤ 4	1.18	3.84	1.18	3.84