ELSEVIER

Agricultural Economics 20 (1999) 57–67

AGRICULTURAL
ECONOMICS

Co-integration and error-correction modelling of agricultural export supply in Cameroon

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Received 19 October 1995; received in revised form 27 April 1998; accepted 15 May 1998

Abstract

Estimates of factors influencing Cameroon's exports of cocoa, coffee and cotton are derived in a system of equations using the Engle–Granger and Johansen co-integration and error-correction representation procedures. Two co-integrating vectors involving cocoa and coffee exports as endogenous variables are identified in the system while tests for exogeneity of cotton exports are consistent with the independence of cotton from the other two commodities. These findings are corroborated by estimates of a restricted error-correction model which lead to acceptance of the hypothesis that cocoa and coffee exports are indeed determined endogenously to the system and not linked to cotton exports. Statistical significance of the error-correction terms for cocoa and coffee validates the existence of an equilibrium relationship among the variables in each of these co-integrating vectors. The combined short-run dynamic effect of lagged quantities of cocoa and coffee, export/domestic price ratio and GDP jointly explain changes in exports of cocoa whereas lagged quantities exported do not seem to have a significant short-run dynamic effect on changes in coffee exports.

Keywords: Cocoa; Coffee; Cotton; Cameroon; Co-integration; Error-correction representation

1. Introduction

Most sub-Saharan African countries that depend on foreign exchange earnings from exports of primary agricultural products have faced major problems in the last two decades. Hazell et al. (1990) observe that the late 1970s and early 1980s were a period of considerable instability in world agricultural markets in which fluctuating world market prices (e.g. for coffee), unstable currency exchange and interest rates led to major instability in export earnings. In the Republic of Cameroon, export earnings from agricultural commodities rose in absolute value from US$ 158 million in 1969–1971 to US$ 600 million in 1979–1981 but dropped to US$ 488 million in 1992–1994 (Table 1). Cocoa, coffee and cotton are the main traditional export commodities. Earnings from these three commodities account more than half of the total agricultural export earnings and about one-quarter of total merchandise exports. Total export earnings from these commodities rose from US$ 109 million in 1969–71 to US$ 346 million in 1979–81 but dropped by 28 percent to US$ 249 million in 1992–94. The relative share of these commodities in total agricultural exports, however, dropped from 69 to 51 percent.

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PII: S0169-5150(98)00068-1

Table 1
Value of agricultural exports ($ million) and percentage in total merchandise exports

Product	1969–1971	1974–1976	1984–1986	1989–1991	1990–1991	1992–1994
Value of total: Merchandise exports	223	474	1191	797	1108	1284
Agricultural exports	158	343	601	522	593	488
Percent of total merchandise	71.0	72.4	50.4	65.5	53.5	38.0
Value of cocoa exports	59	130	239	159	146	140
Percent of total merchandise	27	27	20	20	13	11
Percent of total agricultural	37.3	37.9	39.8	30.5	24.6	28.6
Value of coffee exports	39	32	60	69	45	42
Percent of total merchandise	17	7	5	9	4	3
Percent of total agricultural	24.5	9.3	10.0	13.2	7.6	8.7
Value of cotton exports	11	27	47	16	75	67
Percent of total merchandise exports	5	6	4	2	7	5
Percent of total agricultural	6.9	7.9	7.9	3.1	12.6	13.7
Total value of cocoa, coffee and cotton exports	109	189	346	244	266	249
Percent in: Total merchandise exports	49	40	29	31	24	19
Agricultural exports	68.8	55.1	57.7	46.8	44.8	51.0

Source: Computed from FAO (1994) Country Tables: Basic data on the agricultural sector.
Economic and Social Policy Dept., Rome, 1992; MINAGRI/DS and ONCPB reports.

Similarly, the share in total merchandise exports dropped from 49 to 19 percent (Table 1). Between 1985 and 1994, growth in export earnings from cocoa, coffee and cotton was negative. While domestic production of cocoa and cotton increased, production of coffee declined by an average of 3 percent per year between 1980 and 1994 (Table 2).

The continuous decline in foreign exchange earnings from exports has important implications for Cameroon, whose future economic growth and debt servicing depends on export earnings. This paper examines whether changes in agricultural commodity export prices, the national product and the foreign exchange rate have important effects on the volume of

Table 2
Compound growth rates (%) of export earnings, domestic production, export and domestic prices of cocoa, coffee and cotton in Cameroon

Product	1970–1975	1975–1980	1980–1985	1985–1990	1990–1991
Cocoa					
Export earnings	17.2	23.6	11.0	−6.3	−2.8
Domestic production	−3.0	4.1	0.5	3.4	3.6
Domestic price	8.9	18.2	8.4	0.9	2.2
Export price (fob)	18.8	9.3	14.9	−7.4	−2.4
Coffee					
Export earnings	6.7	20.3	9.9	−2.6	−3.8
Domestic production	0.0	6.8	−3.8	−1.7	−2.8
Domestic price	4.5	12.5	8.4	2.9	2.4
Export price (fob)	13.2	11.9	11.7	−11.7	−4.8
Cotton					
Export earnings	20.2	29.9	14.1	0.1	−6.3
Domestic production	5.2	11.2	6.5	2.8	3.2
Domestic price	7.5	13.2	14.1	2.0	3.1
Export price (fob)	7.8	11.3	16.3	4.6	3.6

Source: Growth rates for export earnings are computed from IMF International financial Statistics data. Rates for domestic production and prices are computed from MINAGRI/DS and ONCPB data, respectively.

commodities exported from Cameroon. Reliable estimates of the determinants of export earnings are essential for policy decision to foster the process of economic development. Previous empirical studies of determinants of export supply in developing countries (Bale and Lutz, 1981; Pollard and Graham, 1985; Bhatia, 1992; Fedani, 1993; Madi, 1993) suffer from methodological shortcomings, which in most cases, invalidate their results and interpretations. This study uses co-integration and error-correction representation to analyze Cameroon's export supply of cocoa, coffee and cotton.

2. Methods

2.1. Co-integration and error-correction representation

Co-integration has assumed increased importance in analyses that purport to describe long-run or equilibrium relationships. An equilibrium relationship exists when variables in the model are co-integrated. A necessary condition for integration, however, is that the data series for each variable involved exhibit similar statistical properties, that is, be integrated to the same order with evidence of some linear combination of the integrated series. A variable is integrated of order $I(1)$ when it is stationary in level form. A stationary series X_t, for example, has a mean, variance and autocorrelation that is constant over time. However, most economic series tend to exhibit non-stationary stochastic processes of the form

$$X_t = \alpha + \beta X_{t-1} + e_t \quad (1)$$

where α is a constant drift, β=1, and e_t is an error term. If e_t has zero mean, constant variance and zero covariance, then X_t is a random walk and is said to be integrated of order $I(1)$. The series X_t is integrated because it is the sum of its base value X_0 and the differences in X up to time t. Since β is unity, X is said to have 'unit root.' If X_t is non-stationary, the variances may become infinite and any stochastic shock may not return to a proper mean level. As shown by Engle and Granger (1987), such a non-stationary series has no error-correction representation.

A non-stationary series requires differencing to become stationary. X_t is integrated of order D_x or $X_t \sim I(D_x)$ if it is differenced D_x times to achieve stationarity. Engle and Granger (1987) provide appropriate tests for stationarity of individual series as the Dickey–Fuller (DF) and augmented Dickey–Fuller (ADF) statistics. These tests are based on t-statistics on δ obtained from estimates of the following respective static OLS regressions applied to each of the series:

$$\Delta X_t = \alpha + \delta X_{t-1} + e_t \text{ (for the DF test)} \quad (2)$$

$$\Delta X_t = \alpha_0 + \delta X_{t-1} + \sum_{t-1}^{k} \beta \Delta X_{t-1} 1 + e_t \text{ (for the ADF test)} \quad (3)$$

where the lag length k chosen for ADF ensures that e_t is empirical white noise. H_o holds that X is $I(1)$ as against H_a being $I(0)$. H_o is rejected if the t-statistic on δ is negative and statistically significant when compared to appropriate critical values established for stationarity tests. These critical values have been established by a number of studies from Monte Carlo simulations (Fuller, 1976; Dickey and Fuller, 1981; Engle and Granger, 1987; Phillips, 1987; Perron, 1988; Blangiewicz and Charemza, 1990). Most of the critical values are appropriate for large samples. However, critical values for small samples of 15–50 observations are available in Blangiewicz and Charemza (1990).

Once the stationarity properties of the individual series are established, linear combinations of the integrated series are tested for co-integration. If a set of these series (e.g. $X_t \sim I(D_x), Y_t \sim I(D_y)$ and $Z_t \sim I(D_z)$ are integrated of the same order $I(P)$, then they form a co-integrating set. Consider a linear combination of these series,

$$M_t = \alpha_0 + \beta_1 \ln X_t + \beta_2 \ln Y_t + \beta_3 \ln Z_t + e_t \quad (4)$$

where $X_t = I(P')$. The series X_t, Y_t, and Z_t co-integrate if $P' < P$ and the combination produces a residual series e_t that is stationary.

The relationship in Eq. (4) is a co-integrating regression of order (P') with co-integrating parameter β. Two or more series co-integrate order (P, P') if the individual series are integrated of order $(P - P')$ (Engle and Granger, 1987). Should a linear combination of individual non-stationary series produce a stationary data series, then the variables are co-integrated and unless they co-integrate, they cannot describe equilibrium relationships. If they do not co-integrate, regressions of one $I(1)$ variable to another become spurious. As shown by Granger and Newbold (1974), such regressions produce high R^2s and t-ratios that are biased towards rejecting the H_o of no relationship even when there is no relationship between the variables. Estimates obtained from linear combinations of individual series that are properly co-integrated are reliable and consistent and are fit for describing the steady-state relationships.

A number of studies have provided important expositions of the co-integration methodology along with explicit tests for evaluating the co-integrating properties of a pair of non-stationary series (Hendry, 1986; Engle and Granger, 1987; Johansen, 1988; Johansen and Juselius, 1990; Goodwin and Schroeder, 1991; Hallam et al., 1994). The procedure consists of two steps. First, standard OLS is applied to the levels of the variables to establish the order of integration for particular combinations of the co-integrating variables. Estimates of the residual errors e_t are obtained as follows:

$$e_t = X_t - \alpha - \beta Y_t \tag{5}$$

The H_o that e has a unit root and therefore is a random walk, is tested against H_a that it is stationary using the DF and ADF tests. The DF test is based on OLS estimates of the regression

$$\Delta e_t = -\psi e_{t-1} + \varepsilon_t \tag{6}$$

whereas the ADF test, which is analogous to the DF test, is based on OLS estimates of the regression

$$\Delta e_t = -\psi e_{t-1} + \delta \Delta e_{t-1} + \ldots + \delta \Delta e_{t-k} + \varepsilon_t \tag{7}$$

where e_t is the first stage estimates of the lagged values of thé differenced residual errors and the lag length k is chosen to ensure empirical white noise.

Models with data series that have a long-run equilibrium relationship but have significant short-run divergencies can be given an error-correction representation. For such models, the error correction mechanism captures the short-run dynamics while making them consistent with long-run dynamics. This is accomplished in the second step of the Engle–Granger procedure by estimating an error-correcting model in which residuals from the equilibrium co-integrating regression are used as an error-correcting regressor (EC_t lagged one period) in a dynamic model. As shown by Arize and Ndubizu (1992), the error-correcting adjustment mechanism is expressed as

$$\Delta X_t = \gamma_0 + \gamma_1 \Delta X_t^* + \gamma_2 [X_{t-1}^* - X_{t-1}] \tag{8}$$

where ΔX_t^* is the change in the 'desired' equilibrium level and X_{t-1}^* is the lagged version of Eq. (1). The error-correction equation is then estimated to include EC_{t-1} as a regressor to capture the short-run dynamics.

2.2. Empirical estimation

The general form of the export supply function is specified in double log form as follows:

$$\begin{aligned} \ln QE_{it} = {} & \alpha_0 + \beta_1 \ln P_{it}^{d} + \beta_2 \ln P_{it}^{e} + \beta_3 \ln PR_{it} \\ & + \beta_4 \ln VWT_t + \beta_5 \ln GDP_{it} \\ & + \beta_6 \ln ER_t + \mu_{it} \end{aligned} \tag{9}$$

where $\ln QE_{it}$ is the quantity of the ith commodity exported in thousands of metric tonnes; $\ln P_{it}^{d}$ is the wholesale price index representing the domestic price index (1980=100); $\ln P_{it}^{e}$ is the price of Cameroon's aggregate exports as measured by the export unit value index (1980=100); $\ln PR_{it}$ is the quantity of domestic production of the ith commodity; $\ln VWT_t$ represents the net value of world trade, that is, Cameroon's net export value; lnGDP is Cameroon's gross domestic product measured at factor cost in billion of Francs CFA at constant 1980 prices; $\ln ER_t$ is the exchange rate in terms of units of foreign currencies (US\$) per Cameroon currency (Francs CFA); and μ_{it} is a stochastic error term assumed to be independently and normally distributed with zero mean and constant variance.

Standard supply theory indicates that the partial derivatives of supply of exports with respect to export and domestic prices of export goods are positive and negative, respectively. Since P_{it}^{d} is determined by the factors of supply and demand, the joint inclusion of P_{it}^{e} and P_{it}^{d} in Eq. (9) may lead to multicollinearity. To circumvent this problem, P_{it}^{e} and P_{it}^{d} are replaced by a relative price index defined as P_{it}^{e}/P_{it}^{d}. Eq. (9) thus becomes

$$\begin{aligned} \ln QE_{it} = {} & \alpha_0 + \beta_1 \ln(P_{it}^{e}/P_{it}^{d}) + \beta_3 \ln PR_{it} + \beta_4 \ln VWT_t \\ & + \beta_5 \ln GDP_{it} + \beta_6 \ln ER_t + \mu_{it} \end{aligned} \tag{10}$$

The price ratio P^{e}_{it}/P^{d}_{it} is expected to have a positive effect on QE_{it} and is intended to capture the profitability of exports. The sign of PR_{it} is expected to be positive because higher production results in an increase in exports. The net value of world trade can be positive or negative depending on whether or not exports exceed imports. A negative net value implies an unfavourable balance of trade position. Under such situations, most economies endeavour to increase the exportable surplus so as to off-set the deficit trade balance. Thus, a negative value of world trade increases pressure on exportable surplus. An inverse relationship is therefore expected between the two variables.

On an a priori basis, a direct relationship is expected between QE_{it} and GDP_t, a reflection of the robustness of the economy. ER_t is expected to have a positive effect on net exports. Where exchange rates are highly volatile, variations in net exports become prominent. A higher purchasing power of the domestic currency implies that the exchange rate is lower and vice versa. Higher exchange rates that occur during devaluation of domestic currencies lead to increased exports. Thus, a positive sign is anticipated between the exchange rate and exports.

The data used in this study covered the period from 1965 to 1992. Data for the period 1965–1975 were aggregated from records of the former States of West and East Cameroon that became united in 1972. Data on quantities of cocoa, coffee and cotton exported, wholesale price index and the value of Cameroon's exports were obtained from the reports of *Office Nationale de Commercialisation de Produits de Bases (ONCPB)* of the Ministry of Trade and Industrial Development (MINDIC, 1994). Quantities produced domestically came from various issues of *Annual Statistical Yearbooks* published by the Department of Statistics of the Ministry of Agriculture (MINAGRI, 1995 and previous issues). GDP data were obtained from various issues of National Accounts Yearbooks published *by Direction de Statistique et de Compatabilite Nationale (DSCN)* of the Ministry of Plan and Territorial Administration (MINPAT, 1995). The net value of world trade and exchange rate data were collected from various issues of *International Financial Statistics Yearbook*, published by the International Monetary Fund (IMF, 1994).

2.3. Diagnostic tests results

In Table 3 we present DF and ADF test statistics for unit root of the individual series. For all the variables in level form (except $\ln Pe^{C}_{t}/Pd^{C}_{t}$) the null hypothesis that each series is $I(1)$ cannot be rejected as the ADF statistics are above the critical value of −3.13. Thus, the variables are non-stationary in their level form. In the first difference form, however, we can reject the null hypothesis for all variables except PR^{C}_{t}, PR^{F}_{t}, PR^{T}_{t} and VWT_t that the variables are $I(2)$. Note that upon differencing, all domestic production variables and the

Table 3
Univariate stationarity properties of the individual series

Variable	DF	ADF	Variable	DF	ADF
$\ln QE^{C}_{t}$	−2.488	−1.795	$\Delta\ln QE^{C}_{t}$	−4.468	−3.204
$\ln QE^{F}_{t}$	−2.340	−2.706	$\Delta\ln QE^{F}_{t}$	−3.127	−5.189
$\ln QE^{T}_{t}$	−2.697	−2.398	$\Delta\ln QE^{T}_{t}$	−2.864	−4.793
$\ln GDP_t$	−0.787	−2.323	$\Delta\ln GDP_t$	−2.667	−3.175
$\ln ER_t$	−1.998	−1.983	$\Delta\ln ER_t$	−3.563	−3.085
$\ln P^{d}_{t}$	−1.200	−1.399	$\Delta\ln P^{d}_{t}$	−8.672	−3.986
$\ln P^{e}_{t}$	−1.824	−1.862	$\Delta\ln P^{e}_{t}$	−3.955	−4.121
$\ln P^{e}_{t}/P^{d}_{t}$	0.849	−4.185	$\Delta\ln P^{e}_{t}/P^{d}_{t}$	−5.363	−6.353
$\ln PR^{C}_{t}$	−2.577	−2.821	$\Delta\ln PR^{C}_{t}$	−2.973	−3.118
$\ln PR^{F}_{t}$	−2.316	−2.911	$\Delta\ln PR^{F}_{t}$	−3.009	−3.109
$\ln PR^{T}_{t}$	−2.606	−2.276	$\Delta\ln PR^{T}_{t}$	−2.627	−2.586
$\ln VWT_t$	−0.626	−2.075	$\Delta\ln VWT_t$	−2.617	−2.755

$\ln QE^{C}_{t}$, $\ln QE^{F}_{t}$, $\ln QE^{T}_{t}$, are quantities of cocoa, coffee and cotton exported, respectively.
$\ln PR^{C}_{t}$, $\ln PR^{F}_{t}$, $\ln PR^{T}_{t}$, are quantities of cocoa, coffee and cotton produced, respectively.

Table 4
Engle–Granger tests for long-run equilibrium co-integration

Regressor	Dependent variables					
	$\ln QE_t^C$	$\ln QE_t^F$	$\ln QE_t^T$	$\ln GDP_t$	$\ln ER_t$	$\ln P_{it}^e/P_{it}^d$
$\ln QE_t^C$		0.374 (3.003)	−0.297 (−1.524)	0.219 (2.356)	0.039 (0.968)	−0.136 (−2.194)
$\ln QE_t^F$	0.117 (3.003)		−0.237 (−0.752)	0.045 (2.081)	−0.278 (−1.894)	−0.023 (−0.608)
$\ln QE_t^T$	−0.041 (−1.524)	−0.106 (−0.752)		0.065 (1.789)	0.068 (0.458)	−0.037 (−1.531)
$\ln GDP_t$	0.917 (2.356)	0.601 (2.081)	1.951 (1.789)		0.968 (1.225)	−0.652 (−2.240)
$\ln ER_t$	0.011 (0.968)	−0.254 (−1.894)	0.138 (0.458)	0.066 (1.225)		−0.038 (−1.088)
$\ln P_{it}^e/P_{it}^d$	−1.323 (−2.194)	−0.719 (−0.608)	−2.594 (−2.531)	1.521 (2.240)	−1.323 (−1.088)	
Intercept	2.959 (3.997)	3.176 (1.978)	2.217 (0.865)	−0.739 (−1.648)	4.769 (3.151)	0.402 (1.343)
R^2 adj.	0.661	0.554	0.486	0.597	0.368	0.572
DW	1.353	2.789	1.178	1.186	0.928	1.135
ADF[a]	−4.825 (5)	−3.675 (2)	−3.066 (2)	−3.025 (2)	−2.835 (3)	−3.005 (2)
Box–Pierce						
$\chi^2(8)$	6.584	2.380	10.006	9.823	14.135	24.205
ARCH$\chi^2(1)$	0.233	0.573	4.014	0.214	1.904	0.058
J–B $\chi^2(2)$	0.569	0.921	6.624	1.152	1.048	1.177
Chow						
$F(6, 16)$	1.206	2.079	3.312	1.490	0.928	2.256

[a] Appropriate lag length required for white noise in parentheses.
DW is the Durbin–Watson statistic. ADF is the augmented Dickey–Fuller statistic with a critical value of 3.13. ARCH is the autoregressive conditional heteroscedasticity statistic with a critical value of 3.84. J–B is the Jarque and Bera statistic with a critical value of 5.99. The critical value for the Box–Pierce statistic is 15.5 while the critical value for the Chow statistic is 2.79.

value of world trade retain a single unit root, implying that they remain non-stationary and therefore may not be fit for inclusion in the analysis.

Given that the other variables exhibit a stationary series, I then proceeded to the estimation of the co-integration equation using the data in level form. In applying the Engle–Granger co-integration test, joint endogeneity for the three export products was assumed. Estimates are presented in Table 4. Before examining whether the ADF statistics support co-integration, it is essential to establish the statistical appropriateness of the residuals. Beneath Table 4 are presented the Box–Pierce (Box and Pierce, 1970) statistics for residual autocorrelation, the autoregressive conditional heteroscedasticity (ARCH) statistic of Engle (1982), the J–B statistic of Jarque and Bera (1980) and the Chow (1960) statistic for structural stability.

The Box–Pierce test statistics for residual autocorrelation are not significantly different from zero, meaning that we cannot reject the null hypothesis of non-autocorrelation of the residuals except for $\ln P_{it}^e/P_{it}^d$. The critical value is 15.5. As can be seen, the residuals appear to be normally distributed except for $\ln QE_i^T$ for which the χ^2 distributed ARCH and J–B statistics are larger than the respective critical values of 3.84 and 5.99 required to reject the null hypothesis of normal residuals at the 5 percent level. For all co-integrating vectors except $\ln QE_i^T$, structural stability of the residuals is guaranteed by the F-distributed Chow test statistics which are all below the critical value of 2.79 at the 5 percent level. From the preceding diagnostics, we conclude that the co-integrating vectors for cocoa and coffee are serially non-autocorrelated, normally distributed and structurally stable. This unfortunately is not the case for cotton exports and other variables.

For all six co-integrating vectors, the ADF statistic is consistent with co-integration in quantities of cocoa and coffee exported but not the quantity of cotton, price ratio, GDP and exchange rate. Thus, the Engle–Granger procedure defines two long-run equilibrium relationships. These co-integrating vectors are associated with quantities of cocoa and coffee exported being endogenous to the quantity of cotton exported. However, looking at the adjusted R^2s, they appear to be lower than normal and therefore, cast some doubts on the explanatory power of the co-integrating vectors. Hendry (1986), (p. 205) argues, for example, that the ability of the Engle–Granger test to detect the presence of co-integration depends on the magnitude of R^2 and that although high R^2s are necessary, they are not a sufficient condition for detecting the presence of co-integration. More importantly, the Engle–Granger procedure assumes that the co-integrating vectors are unique and have well-defined limiting distributions (Hall, 1986). This is often not the case, making hypothesis testing problematic. For more meaningful results, therefore, the possibility of long-run equilibrium relationships among cocoa, coffee and cotton exports from Cameroon using the Johansen procedure were investigated.

Having determined through the Engle–Granger procedure that only two of the six co-integrating vectors exist, the Johansen procedure to test for the existence of more than two co-integrating vectors was applied. The procedure requires dividing series data into two parts – levels – and differenced. Canonical correlations are then used to find linear combinations of the data at levels that are highly correlated with the differences. These highly correlated linear combinations tend to be stationary or co-integrated. For series that are $I(1)$, the differenced data also tend to be stationary. Beginning with the assumption that the variable q_t is generated autoregressively, the Johansen approach provides tests of linear restrictions on the co-integrating vectors, estimates of its elements and information about its rank as follows:

$$q_t = \sum_{i=1}^{r} \pi_t q_{t-1} + \varepsilon_t \qquad (11)$$

where q_t is a six-variable vector: $\mathrm{QE}_t^C, \mathrm{QE}_t^F$, $\mathrm{QE}_t^T, P_{it}^{\mathrm{e}}/P_{it}^{\mathrm{d}}$, GDP_t and ER_{it} and ε_t is a random error term. As a VAR-system Eq. (11) can be reparameterized in first difference form as follows:

$$\Delta q_t = \sum_{i=1}^{r} \Gamma_i \Delta q_{t-i} - \pi_i q_{t-i} + \varepsilon_t$$

with

$$\Gamma_k = -I + \sum_{i=1}^{k} \pi_i,\ k = 1, \ldots, r-1, \pi = I - \sum \pi_i \qquad (12)$$

and π is the coefficient matrix having information about the long-run relationship between the variables and the data vector. For a stationary ε_t, the rank (ρ) of the long-run matrix π determines the number of linear combinations of q_t that are stationary or co-integrated. The determination of π is equivalent to finding whether co-integration exists. If π has full rank, such that $q_t = n$ then all q_t are stationary, whereas if ρ=0 so that π=0, then Δq_t becomes non-stationary and all linear combinations of $q_t \sim I(1)$. If, however, the rank is $0 < \pi < n$, then there are ρ co-integrating vectors with ρ stationary linear combinations of q_t and $(n \times \rho)$ matrices and $\boldsymbol{\beta}$ such that π can be factored as $\pi = \alpha\beta'$. In the system, α and β are the adjustment parameters and the error correction mechanism, respectively (Engle and Granger, 1987).

In applying the procedure, a VAR lag length of 12 was chosen according to the minimum AIC technique. The null hypothesis is that the number of co-integrating vectors is less than or equal to r, where r is 0, 1, 2, 3, 4 or 5. According to the results in column 2 of Table 5, we can reject the null hypothesis of zero co-integrating vectors at the 95 percent level. The trace test procedure yields

$$-2\ln(Q) = -\sum_{i=1}^{6} \ln(1 - \lambda_i) = 250.701 \qquad (13)$$

which is greater than the critical value of 9.094. However, the null hypothesis that $r \leq 1$ or ≤ 2 against the general alternative cannot be rejected. The trace test statistic for $r \leq 2$ is 95.992 which is greater than the critical value. This means that there exist at most two co-integrating vectors. Reflecting on the Engle–Granger test results, we can conclude from the trace test statistics that there is some evidence of the existence of two co-integrating vectors and that these vectors involve cocoa and coffee exports having a long-run equilibrium relationship.

Table 5
Johansen test for the number of co-integrating vectors

H_o	Trace test statistic	Maximum eigenvalue statistic ($\lambda_{\max}$)		
		H_o	H_a	
r=0	250.701	r=0	r=1	93.931
$r \leq 1$	156.770	r=1	r=2	60.778
$r \leq 2$	95.992	r=2	r=3	46.754
$r \leq 3$	29.238	r=3	r=4	31.496
$r \leq 4$	17.742	r=4	r=5	17.678
$r \leq 5$	0.064	r=5	r=0	0.064

Critical values are from Johansen and Juselius, 1990.

The significance of the Engle–Granger and Johansen tests lies in their ability to provide identical evidence of the presence of two long-run equilibrium export supply relationships for cocoa and coffee in Cameroon. Reverting to the objectives of this study, the role of the regressors in explaining this relationship was examined. This was done by estimating the space spanned by the co-integrating vectors. Using the SHAZAM procedure JOHANSEN, the eigenvector matrix is premultiplied by the transpose of the inverse of the Choleski decomposition of the **Skk** matrix to generate the eignvectors that determine the pace spanned by the co-integrating vectors. The normalized eigenvectors (V^*) are presented in Table 6 together with the estimated eigenvalues (λ^*) and the weights (W^*), generated as the product of the **Sok** matrix and V^* (see Johansen and Juselius, 1990, p. 181). The eigenvectors act as an error correction mechanism (β) of the export commodity supply while the weights measure the speed of adjustment (α) towards the long-run equilibrium.

Note how small the coefficients and weights are in column 1 of Table 6, an indication of the slow rate of adjustment towards long-run equilibrium. In fact, these results are in agreement with the hypothesis of zero adjustment, particularly for the macro variables GDP_t and ER_t toward long-run equilibrium. In the case of cocoa exports, the magnitude of adjustment is 0.004, whereas for coffee and cotton, they are −0.004 and −0.001, respectively. Since these coefficients come from unrestricted co-integrating vectors, the hypothesis that the restricted vectors QE_t^C and QE_t^F are the co-integrating vectors using the likelihood ratio statistic was tested

$$-2\ln(Q) = -\sum_{i=1}^{6}\ln[(1-\lambda_i^k)/(1-\lambda_i)] \quad (14)$$

where λ_k and λ_i are the respective eigenvalues of the restricted and unrestricted models. A calculated LR statistic of 5.963 led to a failure to reject the null hypothesis that the restricted vectors are a true representation of the co-integrating vectors. Combining the Engle–Granger and Johansen test results, it is noted that two co-integrating long-run equilibrium relationships exist. These vectors are associated with quantities of cocoa and coffee exported being endogenous to the system. Looking at the t-statistics in Table 4, it would appear that quantities of cocoa (QE_t^C) and coffee (QE_t^F) exported are related, while quantity of cotton (QE_t^T) is not statistically significant (p>0.05) in explaining exports of cocoa and coffee. Apart from being exogenous to quantities exported, GDP is a statistically important variable for cocoa, coffee and cotton exports. However, the price ratio ($\ln P_{it}^e/P_t^d$) is a statistically important variable for cocoa but not coffee and cotton. Except for coffee, the exchange rate

Table 6
Eigenvalues, eigenvectors and weights for commodity exports in Cameroon

Variable	Eigenvalues λ^*					
	0.976	0.912	0.846	0.716	0.507	0.003
	Eigenvectors V^*					
QE_t^C	−0.051	−0.616	−0.212	0.359	−0.027	0.665
QE_t^F	0.753	0.038	0.448	−0.273	0.077	0.387
QE_t^T	−0.476	−0.398	0.652	−0.309	−0.231	−0.007
GDP_t	−0.183	0.042	0.387	0.356	0.829	−0.011
ER_t	−0.005	0.349	0.413	0.673	−0.499	0.071
P_{it}^e/P_{it}^d	−0.413	0.581	−0.084	−0.283	0.049	0.634
	Weights W^*					
QE_t^C	0.004	0.002	0.006	−0.020	−0.003	−0.013
QE_t^F	−0.004	−0.000	−0.003	0.015	0.000	0.011
QE_t^T	−0.001	0.005	0.001	0.043	0.003	0.028
GDP_t	0.000	0.005	−0.004	0.019	−0.009	00.013
ER_t	−0.004	−0.005	−0.010	−0.011	0.000	−0.006
P_{it}^e/P_{it}^d	0.003	−0.002	−0.002	−0.009	−0.001	−0.007

($\ln ER_t$) is not a statistically significant variable for the other commodities.

The exogeneity of cotton exports and the other variables were tested by estimating error-correction models (ECM) of the three export commodities. The following general ECM was constructed and estimated:

$$\begin{aligned}\Delta \ln QE^C_{it} &= \beta_1 + \sum_{i=1}^{n1} \beta_{2i} \Delta \ln QE^C_{t-i} + \sum_{i=0}^{n2} \beta_{3i} \Delta \ln QE^F_{t-i} \\ &+ \sum_{i=0}^{n3} \beta_{4i} \Delta \ln QE^T_{t-i} + \sum_{i=0}^{n4} \beta_{5i} \Delta \ln GDP_{t-i} \\ &+ \sum_{i=0}^{n5} \beta_{6i} \Delta \ln ER_{t-i} + \sum_{i=0}^{n6} \beta_{7i} \Delta \ln P^{e}_{it}/P^{d}_{t-i} \\ &+ \delta \mu_{t-1} + \varepsilon_t \qquad (15)\end{aligned}$$

where the variables $QE^C_t, QE^F_t, QE^T_t, P^e_{it}/P^d_{it}, GDP_t$ and ER_{it} are as previously defined and Δ is the difference operator. QE^C_{t-i} measures the short-run dynamics, μ_{t-1} is the lagged value of the residuals and is included to measure long-run equilibrium adjustment with δ as the error correction coefficient, and εt is a random error term. Eq. (15) is a dynamic ECM of the short-run behaviour of commodity exports, where nj (j=1–6) measures the response of exports to changes in the regressors.

3. Results

Results of the ECM are presented in Table 7 together with diagnostic tests of each equation. The ECM coefficients integrate the short-run dynamics in the long-run export supply relationship. With cotton quantities as a regressant, lagged values of cocoa and coffee do not appear in the specification. Given that the regressants are cast in the first difference, the empirical results indicate a satisfactory statistical fit as judged by the adjusted R^2s. For all the three products, the Box–Pierce statistic for residual autocorrelation does not reject the null hypothesis of no autocorrelation in the residuals. According to the J–B and ARCH tests, heteroscedasticity does not pose any problem for any of the relationships. These test statistics do not reject the hypothesis that the estimated equations possess a normal distribution. Except for the cotton relationship which fails the Chow (1960) test for structural stability, all the relationships are structurally stable.

Table 7
Error-correction model regressions results for agricultural commodity exports in Cameroon

Regressor	Dependent variables		
	Cocoa ($\Delta \ln QE_t$)	Coffee ($\Delta \ln QE^F_t$)	Cotton ($\Delta \ln QE^T_t$)
Intercept	2.596 (4.672)	1.380 (2.454)	0.583 (1.026)
$\Delta \ln QE^C_{t-1}$	0.418 (2.083)	0.401 (1.660)	
$\Delta \ln QE^F_{t-1}$	0.018 (2.118)	0.651 (3.779)	
$\Delta \ln QE^T_{t-1}$	−0.173 (−0.922)	−0.034 (−0.179)	0.040 (1.840)
$\Delta \ln P^e/P^d_{t-1}$	0.161 (1.958)	0.076 (2.450)	−0.171 (−1.875)
$\Delta \ln GDP_{t-1}$	0.026 (2.213)	0.113 (1.926)	0.186 (2.323)
$\Delta \ln ER_{t-1}$	−0.063 (−1.549)	0.126 (1.884)	−0.084 (−2.627)
μ_{t-1}	−0.1014 (−2.398)	−0.548 (−1.960)	−0.169 (−1.683)
R^2 adj.	0.791	0.780	0.630
DW	1.849	1.748	1.722
Box–Pierce $\chi^2(8)$	3.692	4.733	5.261
ARCH $\chi^2(1)$	2.899	0.007	0.294
J–B $\chi^2(2)$	0.464	0.884	1.861
Chow $F(8, 12)$	1.579	1.976	0.948[a]

DW is the Durbin–Watson statistic. ARCH is the autoregressive conditional heteroscedasticity statistic with a critical value of 3.84. J–B is the Jarque and Bera statistic with a critical value of 5.99. The critical value for the Box–Pierce statistic is 15.5 while the critical value for the Chow statistic is 2.85.
[a]Critical value for Chow F (6, 16) is 2.74.

The usefulness of our inclusion of the error-correction term in the restricted Eq. (15) lies in its ability to reduce the number of parameters in the estimating equation by the number of level terms in the co-integrating equations (Arize, 1994). The important finding of this study is that although the error-correction term for the cotton relationship displays the appropriate (negative) sign, it is statistically insignificant (p>0.05), suggesting that quantities of cotton exported are exogenous to the other two export commodities. For cocoa and coffee, the error-correction terms are of the appropriate negative sign and are statistically significant, a finding that is consistent with the validity of an equilibrium relationship among the variables in each co-integrating equation. This means that these two commodities are endogenous to the system.

For cocoa exports, the results in Table 7 reveal that the combined short-run dynamic effect of the lagged quantities of cocoa, and the lagged quantities of coffee exported, the export/domestic price ratio and GDP jointly explain changes in exports. For coffee exports, lagged quantities exported do not seem to have a significant short-run dynamic effect on changes in exports. Rather, the changes in exports are determined jointly by the export/domestic price ratio, GDP and the foreign exchange rate. The statistical significance of μ_{t-1} for cocoa and coffee is thus suggestive of the efficiency of the estimates in Table 7.

4. Conclusion

The Republic of Cameroon earns substantial foreign exchange from exports of cocoa, coffee and cotton. However, major fluctuations in export earnings have raised concern about the country's future growth potential and debt servicing. This paper measures the effects of important determinants of Cameroon's exports of cocoa, coffee and cotton. The Engle–Granger and Johansen procedures for co-integration and error-correction representation are used to test for long-run equilibrium relationships among exports of cocoa, coffee and cotton estimated as a system with the other variables. Of the six equations in the system, only two are co-integrated. These co-integrating vectors involve cocoa and coffee exports being endogenous to the system. For cotton exports which are of concern, tests for exogeneity indicate that cotton exports are independent of cocoa and coffee exports. Estimation of restricted error-correction models for cocoa, coffee and cotton exports provides estimates that lead to the acceptance of the hypothesis that cocoa and coffee are indeed determined endogenously to the system and are not linked to cotton exports.

Statistical significance of the error-correction terms for cocoa and coffee validates the existence of an equilibrium relationship among the variables in each of these co-integrating vectors, a finding which suggests that the two commodities are endogenous to the system. The combined short-run dynamic effect of the lagged quantities of cocoa and coffee, the export/domestic price ratio and GDP jointly explain changes in exports of cocoa whereas for coffee, lagged quantities exported do not seem to have a significant short-run dynamic effect on changes in exports. What determines exports of coffee is the export/domestic price ratio, GDP and the foreign exchange rate. The conclusion from these results is that cotton exports are not a part of the long-run co-integrating system. Exports of cocoa and coffee influence each other just as much as the foreign exchange rate, the level of the national income and the price differential between export and domestic prices do.

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