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The Interdependency of Asset pricing on Prices of Its Substitutes: Application to Cocoa, Coffee and Tea

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Abstract

In this paper we examine the behaviour of the prices, of Cocoa, Coffee and Tea as beverages (substitutes). We also investigate if the pricing of one asset is influenced by the prices of any of the other assets. Using Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) for selecting the best model out of all the competing models, the best models fitted were, Cocoa prices being ARIMA (0, 1, 2), Coffee prices ARIMA (1, 1, 1) and Tea prices ARIMA (0, 1, 0) respectively. Thus, all the three variables were integrated of order I (1), Using Johansen cointegration test, we observed that there was at most one cointegration equation, among these assets, indicating that there is a long-run equilibrium among the pricing of the prices of Cocoa, Coffee and Tea. Analysis of the Granger causality test shows that there is Granger causality between all the three variables; hence there is a long run association among prices of cocoa, coffee and tea. Also from the cross correlation matrix it was observed that all the three variables were positively correlated with cocoa and coffee having a very high correlation of 0.8. This indicates a probable higher dependency of the pricing of these two assets on the price of the other. Due to the cointegration, Vector Error Correction model (VECM) was used to estimate the equation relating the prices of Cocoa, Coffee and Tea.

Keywords

Cointegration, Long-Run Equilibrium, Correlation Matrix, Normality, VECM

1. Introduction

Price plays an important role in marketing as consumers are drawn towards buying cheaper competing commodities, goods or assets. More people are tuning in into virtual marketing where goods are perceived to be cheaper e.g. EBay, Amazon etc. thus for firms to be more competitive and able to survive in the market, there is the need for them to match their prices with the prices of the competitors. This has led to marketing strategies such as "buy one get one free" promotions, and in the airline industry, the introduction of promotional tickets, "fly smile" - mileage rewards, among others. As well as reduction in prices for bulk purchase.

According to Slusky, (1915) [15], the change in the demand for a good, caused by a price change, is the result of two effects: a substitution effect, the result of a change in the relative prices of two goods; and an income effect, the effect of a change in price resulting in a change in the consumer's purchasing power.

Cocoa, Coffee and Tea are agricultural products used mostly as beverages all around the world. Although they may have other uses such as chocolates, medicines, hair products etc these assets are considered economically as substitutes and therefore consumer choice or preference may depend on one of the factors such as price. Demand for an asset depends on consumer preference, taste, income, own price and price of substitutes etc. Buse, (1958) [4], Nerlove, M, (1958) [13], Gardner, B. L. (1976) [7], Koyck, L. (1954) [11]. Therefore there is the need to investigate if the pricing of the assets depends on the prices of its substitutes as stated by the demand theories, Goodwin et al (2009) [8].

Tomek, W. G. (1990) [16], studied the interrelationship of agricultural asset prices through their elasticity. Zainalabidin, M. et al, (2012) [20], studied the interrelationship between prices of Gold, Oil and natural rubber, and concluded that the high volatility in gold and oil prices spill over index causes the price of natural rubber to go up. Vogelvang, E. et al (1991)

[17], also studied the factors affecting the pricing of natural rubber by looking at the effects of its lag prices, crude oil prices and synthetic rubber prices as well as the volume of consumption of natural rubber. Wickramasinghe, (2013) [18], studied the effect of exogenous factors on world rubber natural rubber prices. They considered factors like crude oil prices, synthetic rubber prices, Nikkei Average index, US $ index, Shanghi Composite index, etc.

This study will establish if the pricing of an asset depends on the prices of its substitutes as expected in theory. Also one market can spread easily and instantly to another market which makes financial markets more or less dependent on each other, hence the need to study their interdependency to understand the dynamic structure of the financial economy. This study is also done to add knowledge to the understanding of the interdependency of asset pricing on the prices of its substitutes of the agriculture commodities in the world market.

The Objectives of the study include examining the behaviour of the prices of the individual assets, the total behaviour of the effects of the prices of the assets on each other i.e. if the prices are cointegrated and the interdependency of the pricing of Cocoa, Coffee and Tea among each other.

2. Materials and Methods

2.1. Data Source

A secondary data comprising of the annual prices of Cocoa, Coffee and Tea, from Annual Data (1961-2013), was used. The data was obtained from the World Bank data base pink sheet (updated August 2014) [19].

2.2. Statistical Software

The R software was used in analysing and fitting of the models.

2.3. Methodology

Marshallian Demand function, Nicholson Walter (1978) [14], Green, Jerry et al (1995) [12].

$$Q_x = f\left(P_x, P_y, P_z, ---, P_n, M^0, Preferences\right)$$

$$S_x = f(P_x)$$

Where Q_x is the demand for variable x
S_x is the supply of variable x
P_x is the price of variable x
P_y is the price of variable y
P_z is the demand of variable z
M^0 is income.

Let $X_1,\ X_2\ and\ X_3$ be the individual prices of the assets Cocoa, Coffee and Tea respectively, and X_t the total price with
$X_t = (X_{1t}, X_{2t}, X_{3t})'$ of the assets at time *t*, where a' denotes the transpose of a. Then let a stochastic process {x $_t$:t∈ Z} be an autoregressive moving average process of order (p,q) [ARMA(p,q)-process], Anderson, T.W. (1984) [2], then;

$$X^t = \sum_{k=1}^{p} \alpha_k\, x^{t-k} + \sum_{k=0}^{q} \theta_k\ \varepsilon_{t-k}$$

with $\{\varepsilon_t\}$ white noise $(0, \sigma_\varepsilon^2)$, $\alpha_p \neq 0\ \ \theta_q \neq 0$.

The random error ε_t is called the innovation because it represents the part of the observation variable x $_t$ that is unpredictable given the past values $X_{t-1}, X_{t-2}, ---, X_{t-p}$,

2.4. Dickey Fuller Test for Unit Root

Using Dickey Fuller, (1979) [5], test for unit root. We consider an AR (1) model;

$$x_t = \rho x_{t-1} + \epsilon_t$$

where x_t is the variable, and t is time, ρ is a coefficient, and ϵ_t is the error term. A unit root is present if $\rho = 1$. The model would be non-stationary.

The model can be written as

$$\nabla x_t = (\rho - 1)x_{t-1} + \epsilon_t = \delta x_{t-1} + \epsilon_t$$

where ∇ is the first difference operator. This model can be estimated and testing for a unit root, which is equivalent to testing $\delta = 0$ (where$\delta = \rho - 1$).

2.5. Johanson Cointegration Test

Using the Johansen test for cointegration with the null hypothesis for the trace test, the number of cointegration vectors *r* =0, then, we have for a VAR (*p*) model:

$$X_t = \omega + \varphi_p X_{t-p} + \cdots + \varphi_1 X_{t-1} + \epsilon_t \ \ where\ t = 1, \ldots, T$$

We have two possible specifications for error correction:

1. The long run VECM:

$$\Delta X_t = \omega + \varphi_p X_{t-p} + \Gamma_{p-1}\Delta X_{t-p+1} + \cdots + \Gamma_1 X_{t-1} + \epsilon_t \ \ where\ t = 1, \ldots, T$$

where

$$\Gamma_i = \varphi_1 + \cdots + \varphi_i - I, where\ i = 1, \ldots, p-1.$$

2. The transitory VECM:

$$\Delta X_t = \omega - \varphi_p X_{t-p} + \Gamma_{p-1}\Delta X_{t-p+1} - \cdots - \Gamma_1 \Delta X_{t-1} + \varphi X_{t-1} + \epsilon_t \ \ where\ t = 1, \ldots, T$$

Where

$$\Gamma_i = \left(\varphi_{i+1} + \cdots + \varphi_p\right), where\ i = 1, \ldots, p-1$$

Note: 1 and 2 are the same for both VECM (Vector Error Correction Model) when,

$$\varphi = \varphi_1 + \cdots + \varphi_i - I$$

2.6. Correlation Matrix (CCM)

We define the mean vector and the covariance matrix by Andrews, Moynihan (1990) [3], Ahn, Reinsel (1990) [1] as:

$\mu = E(X_t)$ is the k-dimensional vector of the unconditional expectations of X_t and

$$\Gamma_0 = E[X_t - \mu][X_t - \mu]'$$

Where Γ_0 is a $k \times$ k matrix and $\mu = (\mu_1, - - -, \mu_k)'$ and the $(i,j)^{th}$element of Γ_0 is the covariance of X_{it} and X_{jt}.

Let D be a $k \times$ k matrix diagonal matrix consisting of the standard deviations of X_{it} for $i = 1, - - -, k$.

Then

$$D = diag[\sqrt{\Gamma_{11}(0)}, - - -, \sqrt{\Gamma_{kk}(0)}]$$

The lag-zero cross-correlation matrix (CCM) of X_t is given by

$\rho_0 = [\rho_{ij}(0)] = D^{-1}\Gamma_0 D^{-1}$ Where $\rho_{ij}(0) = \rho_{ji}(0)$ and $-1 \le \rho_{ij}(0) \le 1$ and $\rho_{ii}(0) = 1$ for $1 \le i, j \le k$. Thus $\rho(0)$ is a symmetric diagonal matrix with unit elements. This is used to measure the strength of the linear dependence between the time series variables.

2.7. Test for Normality

Testing the normality of the residuals using the test statistic Jacque-Bera, (1980) [9], is defined as

$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(k-3)^2\right)$$

where *n* is the number of observations (or degrees of freedom in general); *S* is the sample skewness, and *K* is the sample kurtosis:

$$S = \frac{\hat{\mu}_3}{\hat{\sigma}^3} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{3/2}}$$

$$K = \frac{\hat{\mu}_4}{\hat{\sigma}^4} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{2}}$$

3. Results and Discussion

3.1. Behaviour of the Data

The time series plot, figure 1.0 showing the behaviour of the world prices of the variables Cocoa, Coffee and Tea between 1960-2013. Cocoa (black) and Coffee (red), showing similar characteristics of high prices between 1978-1980 and both prices dropping around 1982. Similar patterns are depicted by Tea(blue) prices, although not as high as the movement of cocoa and coffee prices.

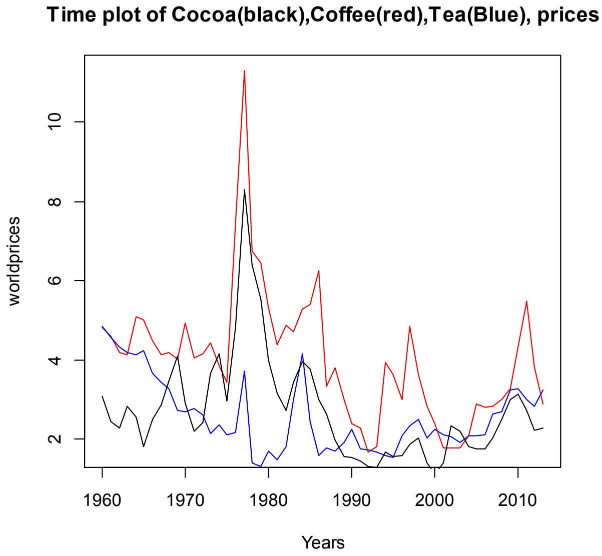

Figure 1. Time plot of world prices of Cocoa (Black), Coffee (Red) and Tea (blue).

The summary statistics of prices of Cocoa, Coffee and Tea, between 1960–2013 is given in Table 1.0 below:

Table 1.0. Statistical Summary of Cocoa, Coffee and Tea prices.

Variable	Obs	Mean	Std. Dev	Min	Max
Cocoa Price	54	2.737593	1.326333	1.14	8.29
Coffee Price	54	4.059074	1.658776	1.69	11.3
Tea Price	54	2.585741	.9074214	1.32	4.86

From Table 1.0, it can be observed that the average price of cocoa between the period 1960-2013 was USD 2,738 per tonne with a minimum price of USD 1,140 and maximum of USD 8,290 per tonne. Also it could be observed that the average price of coffee, between the period 1960-2013 was USD 4,059 per tonne with a minimum price of USD 1,690 and maximum of USD 11,300 per tonne. An average tea price was USD 2,586 per tonne, with a minimum price of USD 1,320 per tonne and a maximum price of USD 4,860 per tonne between the periods 1960-2013.

3.2. Dickey Fuller Unit-Root Test

To be able to establish the order of the series, given on table 2.0 below is the results of the Augmented Dickey Fuller, (1979) [5], unit-root test to investigate if the series of the price of Cocoa, Coffee and Tea were stationary.

Considering the results from Table 2.0, we fail to reject the null hypothesis that there is unit root at all the critical values (i.e 1%, 5%, and 10%) since all the p-values (P>0.05) for all the variables. Since the variables are non-stationary at the level (I(0)), we therefore examine the behaviour of the individual prices of cocoa, coffee and tea.

3.3. Model Selection for the Individual Assets

To understand the behaviour of the individual prices of the variables, a model was fitted for each variable using Akaike

Information Criterion (AIC), Schwarz Information Criterion (SIC) as selection criteria for the individual asset price for the best model of all the competing models, the summary of the results is given below;

Table 2.0. *Dickey-Fuller test for unit root results for Cocoa, Coffee and Tea prices.*

Variable	Test statistic	1% critical value	5% critical value	10% critical value	p-value
Cocoa	-2.324	-3.576	-2.928	-2.599	0.4445
Coffee	-3.0407	-3.576	-2.928	-2.599	0.1554
Tea	-2.0845	-3.576	-2.928	-2.599	0.5405

Table 3.0. *Model for Cocoa Price.*

ARIMA (0, 1, 2)	Constant	ma1	ma2
Coefficients	-0.0089	0.0798	-0.3438
s.e	0.1003	0.1445	0.1413

AIC=128.57, AICc=129.06, BIC=134.48, log likelihood=-61.29

From Table 3.0, the best model for the Cocoa price is ARIMA (0, 1, 2) based on the selection criteria.

Below is Table 3.1, summarizing the results for the model selected for coffee price.

Table 3.1. *Model for Coffee Price.*

ARIMA (1, 1, 1)	Constant	ar1	ma1
Coefficients	-0.0449	0.6530	-0.9327
s.e	0.0365	0.1483	0.0833

AIC=176.33, AICc=176.2, BIC=182.24, log likelihood=-85.16

From Table 3.1, the best model for Coffee price is ARIMA (1, 1, 1).

Model for Tea Price

ARIMA (0, 1, 0)

AIC=93.99 AICc=94.07 BIC=95.96 log likelihood=-46.0

The best model base on the selection criteria for Tea price was an ARIMA (0, 1, 0).

Using Johanson test for cointegration we determine if there is co-integration among the variables since they were all integrated of order I(1).

3.4. Johansen Test for Cointegration

We investigate, if Cocoa, Coffee and Tea, have a long-run equilibrium by performing a cointegration test (Johansen, S. 1988) [10], with Null hypothesis: There is no cointegration as against the Alternative: There is cointegration.

Table 4.0. *Johansen cointegration Rank Test(Trace) for Cocoa, Coffee and Tea prices.*

Hypothesized No. of CE(S)	Eigenvalue	Trace statistics	5% critical value	P-values
None*	0.330784	32.23556	29.79707	0.0257
At most 1	0.143796	11.75152	15.49471	0.1692
At most 2	0.072419	3.83395502	3.841466	0.0502

From Table 4.0 we observe that, at Rank (0) the Trace statistic is 32.24 which is greater than 29.79 at the 5% critical value with $p<0.05$ hence we rejected that there is zero cointegration. The trace test indicates 1cointegration at 0.05 level with the trace statistic of (At most 1 < 0.05 critical value. Thus there may be a long run association among Cocoa, Coffee and Tea prices. Therefore we used the Vector Error Correction (VECM)-model proposed by Engle, Granger et al (1987) [6], since there is at least one cointegration equation.

3.5. Granger Causality

The results of the Granger Causality test at lag (1) is given below on Table 5.0.

Table 5.0. *Granger Causality Test at lag(1) for Cocoa, Coffee and Tea prices.*

Null Hypothesis	Obs	F-Statistic	P-values
Coffee does not Granger cause Cocoa	53	0.59501	0.5557
Cocoa does not Granger cause Coffee		2.27799	0.1137
Tea does not Granger cause Cocoa	53	0.17988	0.8359
Cocoa does not Granger cause Tea		2.14897	0.1279
Tea does not Granger cause Coffee	53	0.48335	0.6197
Coffee does not Granger cause Tea		1.26826	0.2908

From Table 5.0, we rejected the Null Hypothesis that coffee does not Granger cause Cocoa since ($P>0.05$) and vice versa. Also, we rejected that tea does not Granger cause cocoa and vice versa. Nor was it all for, we rejected also that tea does not Granger cause coffee and vice versa. Hence there is a long run association among cocoa, coffee and tea prices.

3.6. Selection of the Lag Length

The optimum lag length was selected based on the selection procedure proposed by Akaike Information Criterion, Schwarz Information Criterion and Quinn Information Criterion. Below is the summary on Table 6.0 showing the results of the lag selection.

Table 6.0. *Lag selection using AIC, HQIC and SBIC.*

lag	LL	LR	Df	P	FPE	AIC	HQIC	SBIC
0	-207.18				.899051	8.4072	8.45089	8.52192
1	-152.729	108.9	9	0.000	.146102*	6.58915*	6.7639*	7.04804*
2	-146.08	13.297	9	0.150	.161238	6.6832	6.98901	7.48625
3	-137.435	17.29*	9	0.044	.165326	6.6974	7.13427	7.84462

From Table 6.0, using the lag selection criteria of AIC, HQIC and SBIC, a maximum of optimal lag (1) was selected with p-value significant at 5%. Although lag (3) p-value 0.044<5% is significant, but none of the selection criteria selected it, hence it was not included in the determination of the model.

3.7. VECM-Model

Vector Error Correction model (VECM) was used to estimate the equation relating the three variables. Below is the summary of the results on tables 7.0, 8.0 and 9.0.

Table 7.0. *Vector error-correction model for variable Cocoa.*

Variables –D_Cocoa	Coef.	Std. Err.	z	P>|z|
L1	-.1090756	.1870127	-0.58	0.020
Cocoa				
LD	.0780228	.2123717	0.37	0.013
Coffee				
LD	.0857342	.1435559	0.60	0.050
Tea				
LD	-.0599123	.2321635	-0.26	0.006
Constant	-.0071685	.1178928	-0.06	0.002

In Table 7.0, the error correction term L1 for cocoa is significant hence there is long run causality between cocoa, coffee and tea. Also there is long run causality among cocoa, coffee and tea respectively.

Table 8.0. *Vector error-correction model for Variables Coffee.*

Variables –D_Coffee	Coef.	Std. Err.	z	P>|z|
L1	.8291992	.273694	3.03	0.002
Cocoa				
LD	-.486812	.1435559	-1.57	0.007
Coffee				
LD	.3285085	.2100947	1.56	0.018
Tea				
LD	-.0599123	.3397724	-0.45	0.049
Constant	-.0029004	.1725367	-0.02	0.007

From table 8.0, the error correction term L1 for coffee is significant hence there is long run causality between coffee, cocoa and tea. There is also long run causality between cocoa, coffee and tea since all the parameter estimates are significant respectively.

Table 9.0. *Vector error-correction model for Variables Tea.*

Variables –D_Tea	Coef.	Std. Err.	z	P>|z|
L1	-.0514832	.1290594	-0.40	0.000
Cocoa				
LD	-.2058603	.1465599	-1.40	0.010
Coffee				
LD	.0458994	.0990694	0.46	0.043
Tea				
LD	-.0387062	.1602184	-0.24	0.009
Constant	-.0315265	.0813591	-0.39	0.008

From Table 9.0, the error correction term L1 for tea is significant hence there is long run causality between tea cocoa and coffee. Also there is long run causality between tea, cocoa and coffee respectively since all the parameter estimates are significant.

3.8. Diagnostic Test

3.8.1. Autocorrelation Test

Using the Lagrange-multiplier test, we tested for autocorrelation at lags 1 and 2 with Null hypothesis: H0: no autocorrelation at lag order. Table 10 show the summary of results:

Table 10.0. *Lagrange-multiplier test for autocorrelation.*

Lag	chi2	df	Prob > chi2
1	7.8042	9	0.55399
2	17.8742	9	0.03666

From Table 10, with probability of 0.55 in which p>0.05 at order lag 1; we therefore fail to reject the Null hypothesis. Hence there is no autocorrelation at the lag order (1).

3.8.2. Normality Test

Using Jarque-Bera, we tested for normality in the residuals with Null hypothesis: H0: residuals are normally distributed. Table 11 shows the results.

Table 11.0. *Jarque-Bera normality test for the residuals.*

Equation	chi2	df	Prob > chi2
D_Cocoa	0.393	2	0.82166
D_Coffee	0.869	2	0.64746
D_Tea	0.386	2	0.82443
ALL	1.648	6	0.94904

From table 11, we observed that all the probability values of the variables including the overall have $p>0.05$, we therefore fail to reject the Null hypothesis. Hence we may conclude that the residuals are normally distributed.

3.8.3. Correlation Matrix

As proposed by Andrew, Moynihan (1990) [3], below is the cross-correlation matrix of the variables summarized in Table 12.

Table 12.0. *Correlation matrix of Cocoa, Coffee and Tea prices.*

Variable	Cocoa	Coffee	tea
Cocoa	1.0000	0.8371	0.1178
Coffee	0.8371	1.0000	0.2555
tea	0.1178	0.2555	1.0000

From Table 12, the correlation between Cocoa and Coffee is 0.84. This means that there is a strong positive relationship between the pricing of the prices of Cocoa and Coffee, therefore implying that pricing of the assets may depend on the price of the other.

The correlation between Cocoa and Tea price is 0.12 which is positively very low, indicating that the dependency of the pricing of Cocoa may have little influence from the price of tea.

Similarly we observed that the correlation between Coffee and Tea price is 0.26 which is also positive and fairly weak.

4. Conclusions

In examining the behaviour of the prices, among all the competing models, we observed that all the three variables were found to be integrated of order I (1) ,with Cocoa prices being ARIMA (0, 1, 2), Coffee prices ARIMA (1, 1, 1) and Tea prices ARIMA (0, 1, 0) models respectively.

From Johansen cointegration test it was observed that there was at most one cointegration equation, indicating a long-run equilibrium among the pricing of the prices of Cocoa, Coffee and Tea. Further test using Granger causality also shows that there is a long run association among cocoa, coffee and tea prices.

Also from the cross correlation matrix it was observed that all the three variables were positively correlated with cocoa and coffee having a very high correlation of 0.8.

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