

An Econometric Analysis of Cocoa Prices: A Structural Approach

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ABSTRACT

The world market model for cocoa was developed to examine the factors affecting cocoa prices. The models were used to analyse the interrelationship between the economic variables of supply, demand, price and stocks. The findings indicate that the important determinants of cocoa prices are the stock levels and consumption.

ABSTRAK

Satu model pasaran dunia koko telah dibina untuk mengkaji faktor-faktor yang mempengaruhi harga koko. Model ini telah diguna untuk menganalisis hubungkait antara pembolehubah ekonomi seperti penawaran, permintaan, harga dan stok. Hasil kajian menunjukkan penentu penting bagi harga koko adalah paras stok dan penggunaan.

INTRODUCTION

The cocoa industry is vulnerable to price fluctuations arising from changes in the world economic forces such as fundamental factors of supply and demand. Such price variability is of significant importance to the producing countries as it can affect the producers' return and national export earnings.

The current cocoa price trend is not optimistic. While the demand for cocoa continues to expand, supply increases even faster. The average annual growth rates from 1979/80 to 1989/90 for world consumption (proxied by cocoa grinding) and production were 3.5 percent and 4.3 percent respectively. The ratio of stocks to world grinding in 1989/90 crop year was 0.63 compared to 0.32 in 1979/80. At the end of September 1990, cocoa surplus was estimated at 1.4 million tonnes, causing a sharp decline in the cocoa prices. This study attempts to investigate the main factors that determine cocoa prices.

METHODOLOGY

The world cocoa market model was formulated. The model consists of three behavioural equations and an identity. The behavioural equations describe the production, consumption and price of cocoa. The model is closed by an identity which defines the stock of cocoa.

PRODUCTION OF COCOA

The specification of the supply response is based on the model developed by Wickens and Greenfield (1973) and as adopted by Dowling (1979). This model is an improvement over the earlier models developed by Nerlove (1958) and Behrman (1965) in terms of capturing the distributed lag in supply response especially for perennial crops like cocoa. The Wickens and Greenfield model consists of three structural relationships, viz (1) the vintage production function which reflects the constraint of potential output on production; (2) the investment function which reflects the long gestation lag in perennial crop potential production; and (3) the harvesting function which reflects the short run harvesting decision. The estimated equation is derived as the reduced form solution of the above equations.

VINTAGE PRODUCTION FUNCTION

In the vintage production function, the potential production is a function of average yield of the trees and the number of trees in production. It reflects the constraint of the potential output.

$$q^p_t = \sum_{i=0}^n d(i,t) I_{t-i} \quad (1)$$

where,

q^p_t is the potential (optimal) production;

$d(i,t)$ is the average yield of the trees; and

I_{t-i} is the number of trees planted in i years ago which have survived in year t .

Technological progress occurs if $d(i,t)$ is a positive function of time. Both embodied and disembodied technical progress may be included in $d(i,t)$. If embodied technical progress (e.g., new strains) occurs at a constant rate Φ and disembodied technical progress

(e.g., fertiliser effect) at rate θ , then $d(i,t) = (1 + \theta)^t (1 + \Phi)^{t-i} d_i$ where d_i is the yield of a tree age i years. Dowling (1979) assumed $d(i,t) = d_i$ as the use of the Almon technique (Almon 1965) requires fixed parameters on the distributed lag coefficients of past prices. Therefore equation (1) becomes;

$$q^p_t = \sum_{i=0}^n d_i I_{t-i} \quad (2)$$

INVESTMENT FUNCTION

The decision to invest in the perennial crop like cocoa is based on the expected discounted income stream from the investment. The investment function is derived from a formal optimising model. The net present value is given by;

$$V = \sum_{i=0}^{\infty} (1+r)^{-i} \{ (P^e_t - S^e_t) q^p_t - F_t - f_1(I_t) \} \quad (3)$$

where,

- V is the expected discounted net revenue;
- r is the rate of discount;
- P^e_t is the expected unit price of cocoa;
- S^e_t is the unit cost of harvesting of the crop when all potential output q is harvested;
- F_t is the fixed cost in year t ;
- $f_1(I_t)$ is the planting cost with $f'_1(I_t) > 0$, $f''_1(I_t) < 0$; and
- I_t is the number of trees in year t .

Maximizing V subject to the production function in (2), the Lagrangean function is,

$$\begin{aligned} L &= V + \Phi_t \left(q^p_t - \sum_{i=0}^n d_i I_{t-i} \right) \\ &= \sum_{i=0}^{\infty} (1+r)^{-i} \{ (P^e_t - S^e_t) q^p_t - F_t - f_1(I_t) \} \\ &\quad + \Phi_t \left(q^p_t - \sum_{i=0}^n d_i I_{t-i} \right) \end{aligned} \quad (4)$$

The solution of the maximization problem in (4) gives the rate of investment on a commodity as;

$$\begin{aligned}\delta f_1 / \delta I_t &= \sum_{i=0}^n (1+r)^{-i} (P_{t+i}^e - S_{t+i}^e) d_i \\ &= R_t^e\end{aligned}\quad (5)$$

Investment in cocoa is undertaken up to the point where the marginal cost in one or more trees is equal to the expected discounted net revenue obtained from the future production of the tree. The assumption that $f_1(I_t)$ is convex is used to determine the rate of investment.

If $f_1(I_t)$ is quadratic function of I_t , then the investment function derived from $\delta f_1 / \delta I_t$ is,

$$I_t = \beta_0 + \beta_1 R_t^e \quad (6)$$

where,

$$R_t^e = \sum_{i=0}^n (1+r)^{-i} (P_{t+i}^e - S_{t+i}^e) d_i$$

Therefore investment is a function of the expected prices P_t^e . Since the expected prices are not observable, Dowling (1979) assumed that the expected prices can instead be represented by current and distributed lag of past prices. It was also assumed that the lag declines geometrically with lag length and the expected prices are formed adaptively.

$$I_t = \beta_0 + \sum_{i=0}^n w_i P_{t-i} \quad (7)$$

where,

$$w_i = \beta \Phi^i \quad 0 < \Phi < 1$$

Therefore,

$$\begin{aligned}I_t &= \beta_0 + \beta \sum_{i=0}^n \Phi^i P_t \\ &= \beta_0 + \{\beta / (1 - \Phi L)\} P_t\end{aligned}\quad (8)$$

where L is the lag operator.

Wickens and Greenfield (1973) and Dowling (1979) have assumed a constant planting density throughout where trees removal and abandonment are relatively small. Thus the change in acreage can be the proxy for number of trees planted. Therefore the actual planted trees, I_t^a :

$$I_t^a = \Delta A_t$$

From (8),

$$I_t = (1 - \Phi L) = \beta_0(1 - \Phi L) + \beta P_t \quad (9)$$

$$I_t - \Phi I_{t-1} = \beta^*_0 + \beta P_t \quad (10)$$

$$I_t = \beta^*_0 + \beta P_t + \Phi I_{t-1} \quad (11)$$

where,

$$\beta^*_0 = \beta_0(1 - \Phi L)$$

Therefore,

$$\Delta A_t = \beta^*_0 + \beta P_t + \Phi \Delta A_{t-1} \quad (12)$$

Lagging (11) by i ,

$$I_{t-i} = \beta^*_0 + \beta P_{t-i} + \Phi I_{t-1-i} \quad (13)$$

$$= \beta_0 + \beta/(1 - \Phi L) P_{t-i} \quad (14)$$

HARVESTING FUNCTION

The harvesting function represents short-run supply behaviour, which depends on the potential production. The degree of exploitation of the potential output depends on the profitability of doing so. It is determined by recent cocoa prices. Therefore actual production is some function of potential output and distributed lag prices.

$$q_t = a_0 + a_1 q^p_t + \sum_{i=0}^m b_i P_{t-i} \quad (15)$$

where,

q_t is the actual production;

q_t^p is the potential output;

b_i is the harvesting response toward prices; and

m is length of lag and is assumed to be small.

THE REDUCED FORM

Solving equation (2), (14) and (15) gives;

$$\begin{aligned}
 q_t &= a_0 + a_1 \left[\left(\sum_{i=0}^n d_i \beta_0 \right) + d_i \beta \sum_{i=0}^n \Phi^i P_{t-i} \right] \\
 &\quad + \sum_{i=0}^m b_i P_{t-i} \\
 q_t &= a_0 + a_1 d_i \beta_0 + d_i a_1 \beta \sum_{i=0}^n \Phi^i P_{t-i} \\
 &\quad + (1 - \Phi L) \sum_{i=0}^m b_i P_{t-i} + \Phi q_{t-1}
 \end{aligned} \tag{16}$$

Expanding (16) and collecting terms (Dowling, 1979);

$$q_t = \text{constant} + \Phi q_{t-1} + \sum_{i=0}^n t P_{t-i} \tag{17}$$

where,

$$\begin{aligned}
 t &= d_i a_i \beta + b_0 && \text{for } i = 0 \\
 t &= d_i a_1 \beta + b_1 - \Phi b_{i-1} && \text{for } i = 1, 2, 3, \dots, m \\
 t &= d_i a_1 \beta - b_m \Phi && \text{for } i = m + 1 \\
 t &= d_i a_1 \beta && \text{for } i = m + 2, \dots, n
 \end{aligned}$$

The coefficient of the price will depend primarily on the short-run adjustment coefficient b_i , when the lag is short ($i \leq m$) and will directly proportional to the yield pattern when the lag is long. Since the yield pattern of cocoa flatten after about the sixth or seventh year, estimation is proceeded with the first differene of the supply equation. Maximum lag length of 5 years is allowed in order to have sufficient degrees of freedom.

$$\Delta q_t = \text{constant} + (1 + \Phi) q_{t-1} - \Phi q_{t-2} + \sum_{i=0}^n t^* \Delta P_{t-i} \quad (18)$$

where,

$$\begin{aligned} \Delta q_t &\text{ is the change in production,} \\ t^* &= t && \text{for } i = 0 \\ t^* &= t_i - t_{i-1} && \text{for } i = 1, 2, 3, \dots, n \\ t^* &= -t_{i-1} && \text{for } i = n + 1 \end{aligned}$$

Assuming that t^*_i follow the Almon distributed lag polynomial of second degree (Gujarati 1987:8).

Equation (18) represent the supply equation in its general form. A restriction is imposed that the coefficients of supply lagged by one and two periods together sum to one. For the world cocoa supply, the equation can be specified as follows;

$$WCOQ_t = f(WCOQ_{t-1}, WCOQ_{t-2}, \sum_{i=0}^n t^* WCOP_{t-i}) \quad (19)$$

where $WCOQ$ = world cocoa supply; and
 $WCOP$ = Ghana spot price in London

Cocoa supply is postulated to be some function of production lagged by one ($WCOQ_{t-1}$) and two ($WCOQ_{t-2}$) periods and a distributed lag of current and past prices. Cocoa supply lagged by one and two periods are expected to be positive and negative in their influence respectively. As mentioned earlier the coefficient of the price depends on the short-run adjustment coefficient when the lag is short, and directly proportional to the yield pattern when the lag is long.

DEMAND FOR COCOA

Demand for cocoa is a derived demand as it is used as an input in the production of final products such as chocolate and beverages. The demand equation is derived based on the theory of the firm. The solution to the maximization of the profit function is as in Silberberg (1978);

$$Q = f(P_i, P_{y_i}) \quad i = 1, 2, \dots, n \quad (20)$$

where,

- Q_i = quantity of input i demanded;
- P_i = price of input i and related inputs; and
- P_{y_i} = price of output.

Thus the world demand for cocoa can be specified as,

$$WCOC_t = f(WCOP_t, SOB_t, IPI_t, WCOC_{t-1}) \quad (21)$$

where,

- WCOC = World demand for cocoa;
- WCOP = Ghana Spot price in London;
- SOB = Soyabean oil prices; and
- IPI = Industrial production index of the industrial nations

The prices of final products are proxied by the industrial production index of the industrial nations, while soyabean oil is assumed to be the substitute product for cocoa. The production index, price of substitute and lagged demand are expected to be positive in their influence, while cocoa price is expected to have a negative coefficient.

PRICE OF COCOA

The price determination model follows the model developed by Hwa (1981) and Tan (1984). The observed spot price of cocoa in the market result from partial adjustment of the price towards the price level which would yield stock equilibrium.

$$WCOP = f(WCOI_t, WCOC_t, WCOP_{t-1}, WCOP_{t-2}) \quad (22)$$

Where,

- WCOP = Ghana spot price in London;
- WCOI = World Cocoa Stock; and
- WCOC = World Cocoa Consumption.

Cocoa price ($WCOP_t$) is postulated to be some functions of cocoa stock ($WCOI_t$), demand for cocoa ($WCOC_t$) and cocoa prices lagged by one ($WCOP_{t-1}$) and two periods ($WCOP_{t-2}$). The sign for $WCOC_t$ and $WCOP_{t-1}$ are expected to be positive, while $WCOI$ and $WCOP_{t-2}$ are expected to be negative.

IDENTITY

The model is closed by an identity to ensure completeness of the model. The following identity defined the market clearing condition.

$$WCOI_t = WCOQ_t - WCOC_t + WCOI_{t-1} \quad (23)$$

Stock level ($WCOI_t$) is determined by the difference between production ($WCOQ_t$) and consumption ($WCOC_t$) plus carried over stock ($WCOI_{t-1}$).

A detailed description of the definition and sources of data for the variables in the specified model is given in Table 1. The sample period was from 1965 to 1987. The models were estimated in their natural logarithmic form, using the two-stage least squares. The interaction among and feed back relationship of the variables in the cocoa industry make it especially suited to the simultaneous equation approach.

TABLE 1. Definition of variables and sources of data

Variables	Definition	Sources of Data
WCOQ	world cocoa production	FAO Production Yearbook
WCOC	world cocoa consumption	ICCO Quarterly Bulletin of Cocoa Statistics.
WCOP	World price, Ghana spot London	ICCO Quarterly Bulletin of Cocoa Statistics.
WCOI	world cocoa stock	FAO Production Yearbook
IPI	Industrial production index of industrial nations (1980 = 100)	International Monetary Statistics, IMF
SBOP	soyabean oil prices	Oil World

TABLE 2. Estimated Equations of the World Cocoa Market Model

World Production of Cocoa

$$\begin{aligned} \log(\text{WCOQ})_t = & -0.333 + 1.187 \log(\text{WCOQ})_{t-1} \\ & (4.364) \\ & -0.187 \log(\text{WCOQ})_{t-2} + 0.0873 \log(\text{WCOP})_t \\ & (0.687) \quad (2.444) \\ & + 0.022 \log(\text{WCOP})_{t-1} - 0.013 \log(\text{WCOP})_{t-2} \\ & (1.663) \quad (0.702) \\ & -0.02 \log(\text{WCOP})_{t-3} + 0.003 \log(\text{WCOP})_{t-4} \\ & (1.029) \quad (0.266) \\ & + 0.055 \log(\text{WCOP})_{t-5} \\ & (1.746) \\ R^2 = & 0.803 \quad DW = 2.024 \end{aligned}$$

World Demand for Cocoa

$$\begin{aligned} \log(\text{WCOQ})_t = & 3.782 + 0.269 \log(\text{WCOC})_{t-1} + 0.373 \log(\text{IPI})_t \\ & (4.818) \quad (3.430) \\ & + 0.007 \log(\text{SBOP})_t - 0.073 \log(\text{WCOP})_t \\ & (0.280) \quad (3.817) \\ R^2 = & 0.9301 \quad h = 0.7282 \end{aligned}$$

World Cocoa Price

$$\begin{aligned} \log(\text{WCOP})_t = & -32.269 + 3.541 \log(\text{WCOC})_t + 0.650 \log(\text{WCOP})_{t-1} \\ & (4.309) \quad (3.972) \\ & + 0.111 \log(\text{WCOP})_{t-2} - 1.292 \log(\text{WCOI})_t \\ & (0.715) \quad (5.553) \\ R^2 = & 0.8462 \quad h = 0.6478 \end{aligned}$$

Note: numbers in parentheses are the t values.

RESULT

The estimates of the world cocoa market model are presented in Table 2. The world cocoa supply equation shows that cocoa supply is significantly influenced by the current cocoa price and five-year lagged price. The coefficient estimates on the distributed lag approximates what is expected, with timing of the positive and negative portions consistent with its typical age-yield profile. The coefficient for current price is positive and fall off very rapidly, becoming negative at lag two. This negative effect persists for two periods. The coefficient become positive at lag four and five. Owing to the low lag length, the lag does not show the turning point. However our analysis with longer lag is inferior.

The results suggest the following. High cocoa price encourages investment in cocoa. Since cocoa has a 5-year gestation period, the decision to invest affects cocoa production five years later. However, Hwa (1979), Melo (1973) and Claessens (1984) obtained longer lag effects, as far back as twelve years. This is probably due to the use of better clones and proper management which have significantly shortened the gestation period. Producers are also responsive to changes in prices as shown by the coefficient for the current price.

The estimates obtained for the world cocoa demand equation are consistent with a priori theory. The coefficients for lagged demand, industrial production index of the industrial nations and own price are all significant at one percent level. The industrial production index influences the demand for many commodities such as rubber and palm oil (Mohammed, 1978, 1988a). Current cocoa price is an important determinant of cocoa demand. This finding is consistent with the theory and findings by Behrman (1965), Melo (1973) and Claessens (1984). Previous studies have shown that soyabean oil is the substitute for cocoa (Melo 1973, Behrman 1965 and 1968). However, our analysis does not indicate this to be the case. The coefficient for soyabean oil price is not significant and has an incorrect sign. It is quite plausible as both oils have different melting characteristics, and hence are not perfect substitutes for each other.

All the estimated coefficients in the price equation have the expected signs. Our findings are consistent with the findings by Hwa (1979, 1981) who concluded that the price of cocoa is influenced by stock level, demand and lagged prices. The price elasticities with respect to consumption and stock are 3.54 and -1.29 respectively. This implies that the impact of changes in consumption and stock on price are substantial. The sensitivity of the price of cocoa with stock levels indicates that a one percent decrease (increase) in stock levels will increase (decrease) the price by 1.29 percent. The coefficient on lagged price indicates that the adjustment of price to the equilibrium is relatively fast. The results are consistent with the findings by Hwa (1979) and Mat Nasir et al. (1988) that changes in primary commodity prices are determined by stock disequilibrium, and the speed of price adjustment toward equilibrium is generally faster for agricultural commodities.

SIMULATION RESULTS

A simulation exercise was carried out for the sample period to see the extent the model could track the path of the actual observations. This is basically to validate the model based on its predictive power. It is measured by the root mean square error (RMSE) and root mean square percent error (RMSPE).

Results of the simulation are presented in Table 3. The RMSE and RMSPE for the endogenous variables are good, with the RMSPE obtained less than 10 percent. Thus the model could trace the directions of the actual values quite well.

TABLE 3. Historical Simulation Results

Variables	RMSE	RMSPE
WCOQ	0.0584	0.0154
WCOC	0.0643	0.4524
WCOP	0.3745	8.0618

CONCLUSION AND ECONOMIC IMPLICATIONS

The main objective of this study is to investigate the various factors that influence the cocoa price in the world market. The findings of this study provide a number of insights that are important to the industry.

The results of the analysis suggest that the world cocoa price is determined by the consumption and stock levels. The world cocoa consumption is primarily influenced by the economies of the consuming countries. The price elasticities of supply and demand are low, indicating that the impact of shifts in both supply and demand on cocoa prices are substantial. This shows that price fluctuation is mainly due to the fluctuation in stock levels caused by changes in both supply and demand.

Given the long gestation period in cocoa production, its long productive lifespan and the importance of cocoa to the producing countries, it is therefore essential to have more stable cocoa prices. One way to ensure price stability is through programmes that stabilise stock levels. In the short run, it is difficult to curtail cocoa production due to the perennial nature of the crop. Therefore, stabilization programmes, to be effective, must be implemented

through an effective stock management programme. Our analysis shows that the impact of changes of stock on price is substantial. A one percent change in stock will cause about 1.29 percent change in price. Such programmes should be carried out collectively, as individual nations, such as Malaysia, is too small to influence the world market. The producers are the developing countries, economically weak, while the consumers are the industrial nations in Europe and America.

Management of cocoa consumption is an alternative option that may be used to bolster cocoa prices. Our results indicate that this variable is effective in controlling the world cocoa price. In the effort to encourage consumption, the role of R&D and market promotion which are primarily aimed at increasing demand, are critical. Further downstream activities, such as processing may also be usefull in promoting demand.

The low price elasticity of supply obtained is consistent with previous studies on perennial crops. It is important to formulate policies aimed at increasing the supply elasticity such as through the use of better clones and more downstream processing activities to reduce sharp price fluctuations.

In conclusion, market fundamentals are the main determinants that influence the movement of cocoa prices. Effective management of cocoa stocks and consumption variables is therefore very important in ensuring price stability. The role of the existing international cooperation such as International Cocoa Agreement (ICCA) and Cocoa Producers Alliance (CPA) can be very useful for implementing the cocoa price stabilization programme and encourage demand. For Malaysia, given the small local consumption of the commodity and the small country status of cocoa export in relation to the world cocoa trade, it is imperative, therefore, that Malaysia in order to protect its interest, should participate fully in international forums on cocoa trade, such as the ICCA and CPA. Malaysia's interest would be better served if there is a strengthening of these international organisations.

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