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Working Paper No. 8306

EMPIRICAL STUDY OF WORLD SUPPLY AND DEMAND OF COCOA: 1950 - 1980

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Rehovoth, Israel, P.O.B. 12

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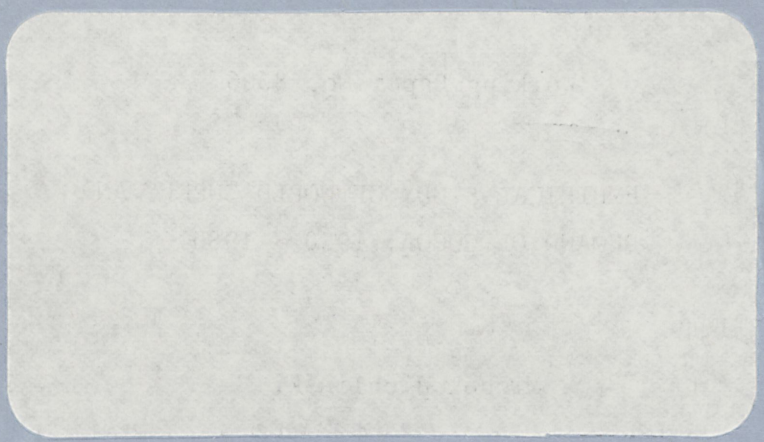

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Michel Jichlinski April, 1983

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INTRODUCTION

This work is concerned with the description of the world supply and demand functions for cocoa. There has been considerable research on this subject and the results are compared with those of the litterature. The model studied is a "mini-model". It has been argued [Adams, 1978] that if the purpose of the research is the forecast of the behavior of a few variables as function of others, simple models are prefered to bigger ones, the purpose of the latter being the study of the structural interrelationships at work in certain markets. It is shown that simultaneous relations should not be ignored, but that all variables on the causal path linking one variable of interest (price) to another (quantity) need not be explicit for our purpose. I am grateful to Yair Mundlak and Haim Shalit for their helpful comments and suggestions.

THE MODEL

The model presented below consists of only three equations: demand, supply and expectation formations. It is a Cobweb model in the sense that supply depends mostly on past information while demand is based on current information.

a) The Demand

The demand for cocoa is defined as the sum of the quantity consumed and of the change in stock in a given period.

$$(1) \quad D_t \equiv C_t + (1 - L)Z_t$$

where:

D_t - demand at year t;

C_t - quantity consumed at year t;

Z_t - stock level at year t;

L - backwards lag operator.

The quantity consumed is a function of the current price and of the income in the world. As will be exposed in the section on data the estimation is on a yearly basis. It is assumed that a year is enough time for the demand to adapt itself to the current conditions:

$$(2) \quad C_t = \alpha_0' + \alpha_1' P_{C_t} + \alpha_2' I_t + \varepsilon_{1t}$$

where:

P_{C_t} - price of cocoa at year y;

I_t - world income at year t;

ε_1 - error term.

The change in stock is a function of the level of supply and demand, reflecting the level of operative stocks, and a function of the difference between the expected price for the next period and the current price, reflecting the level of speculative stocks:

$$(3) \quad (1-L)Z_t = \beta_0' + \beta_1' D_t + \beta_2' (P^e_{C_{t+1,t}} - P_{C_t}) + \varepsilon_{2t}$$

where

$P^e_{C_{t+1,t}}$: expected cocoa price for year t+1, at year t.

Combining (2) and (3) the demand function becomes:

$$(4) \quad D_t = \alpha_0 + \alpha_1 P_{C_t} + \alpha_2 P^e_{C_{t+1,t}} + \alpha_3 I_t + U_{1t}$$

where:

$$\alpha_0 = \frac{\alpha_0' + \beta_0'}{1 - \beta_1'}$$

$$\alpha_1 = \frac{\alpha_1' - \beta_2'}{1 - \beta_1'}$$

$$\alpha_2 = \frac{\beta_2'}{1 - \beta_1'}$$

$$\alpha_3 = \frac{\alpha_2'}{1 - \beta_1'}$$

$$U_{1_t} = \varepsilon_{1_t} + \varepsilon_{2_t}$$

b) The Supply

Cocoa is an orchard product and as such its long term supply is a product of long term expectations while only the marginal changes in supply can be observed in the short term. In other words this is a study of deviations from the production potential, as causing and as caused by changes in the current price level. The long term supply is here treated exogeneously. There exists no physical measure of the production potential but it is assumed to be well described to the previous year's harvest. Coffee competes with cocoa in most producing countries, his price must therefore be introduced in the equation

(5) $S_t = \beta_0 + \beta_1 P_{C_t} + \beta_2 P_{f_t} + \beta_3 S_{t-1} + U_{2_t}$

where:

S_t - supply of year t;

P_{f_t} - price of coffee at year t;

U_{2_t} - error term.

When market is cleared :

(6) $D_t \equiv S_t$

c) The Formation of Expectations

The price expectation for the next period appears in the demand function. The existence of stocks make it obvious that the current price and the expected price are simultaneously formed. The rational expectations hypothesis states that the expectation function process should be based on the model description of the price formation process.

Although this can be discussed, one of the results seems unavoidable. There must be no consistent bias between the expected price and the realized price, because such bias will be observed and corrected for in the long term. It is assumed that:

$$(7) \quad P_{t+1} = P^{e}_{t+1,t} + w$$

where:

w is a white noise process.

Thus the realized price can be used as the expected price measured with an error. The problems of error in variables are of the same nature as the problems caused by simultaneity.

The expectation can only be based on the set of information available at time t. As a rough simplification the expectation is assumed to be based on an autoregresive process of order two.

$$(8) \quad P^{e}_{t+1,t} = \gamma_0 + \gamma_1 P_t + \gamma_2 P_{t-1} + U3_t$$

The equation is purely empirical which is a limitation of the model , but we would be satisfied if the estimator obtained for $U3_t$ cannot be

distinguished from a white noise process, that is if this equation would not leave any systematic component unaccounted for.

d) The Simultaneous Model

Combining (4), (5) and (8), and using Q_t as a symbol for both supply and demand, the estimated model is:

$$\text{Demand} : \quad Q_t = \alpha_0 + \alpha_1 P_{C_t} + \alpha_2 P_{C_{t+1}} + \alpha_3 I_t + U_{1_t}$$

$$\text{Supply} : \quad Q_t = \beta_0 + \beta_1 P_{C_t} + \beta_2 P_{f_t} + \beta_3 Q_{t-1} + U_{2_t}$$

$$\text{Expectation:} \quad P_{C_{t+1}} = \gamma_0 + \gamma_1 P_{C_t} + \gamma_2 P_{C_{t-1}} + U_{3_t}$$

METHODOLOGY

a) The Data

The data sources are described in an annex. The quantity of cocoa is the net world crop. There exists no reliable data on stocks and this is why the stock and the consumption equations were combined into one. Many authors use the world grindings for consumption and the difference between the grindings and net crop for changes in the stock level. This method is dubious since there is no evidence that cocoa cannot be stocked once ground. The prices are commodity exchange prices, which means that they do not reflect entirely the consumer nor the producer price. An attempt was made to correct this bias by dividing this price by the national products of the consuming and of the producing countries but lack of data on the latter forbid this approach. All prices are in US dollars and divided by the US consumer price index. The income of the consuming countries is build by averaging the income per capita of three important consuming countries: the US, the UK and Germany, according to the following

weights: respectively .45, .2 and .35. All incomes are expressed in 1977 dollars. The data covered the period from 1950 to 1980.

b) Estimation Methods

The model was estimated, using the TSP package, according to the following methods:

- Ordinary Least Squares (OLS);
- Two-Stage Least Squares (2LS);
- Three-Stage Least Squares (3LS).

c) Alternative Models

Alternative models were estimated both in terms of specification and of functional form. The "all variables linear" form was preferred because it was found to be superior in terms of the following criteria (the order does not reflect priority):

- Statistical significance and fit;
- Economic meaning;
- Stability of the results to changes of specification.

The price of sugar was introduced in the demand function since it had been found to influence the cocoa market [Behrman, 1965]. It influence here was never statistically significant. The expectation equation was also rephrased where the right hand side variables were current cocoa price and quantity. This seriously affected the results for the worse. The reason could be that this equation became then too similar to the demand equation, thereby causing statistical dependence between the two.

ESTIMATION

a) Identification

The model's endogeneous variables are:

$$Q_t, \ P_{C_t}, \ P_{C_{t+1}} .$$

The predetermined variables are:

$$I_t, \ P_{f_t}, \ Q_{t-1}, \ P_{C_{t-1}} .$$

There are three independent equations so the model is complete. Since there are no homogeneous linear restrictions, the rank condition will be a necessary and sufficient condition for identification. According to this condition, all equations are identified. According to the order condition, all equations are overdentified.

b) Numerical Results

The numerical results are presented in Table 1. Absolute t-ratios appear in brackets.

Table 1

Method	e q u a t i o n	R^2	F
OLS	$Q_t = 465 - 5.82P_{C_T} + .935P_{C_{t+1}} + 350I_t + V_{1_t}$	.91	83.09
	(7.80) (5.89) (1.07) (15.7)		
	$Q_t = 218 - .815P_{C_t} - .655P_{f_t} + .896Q_{t-1} + V_{2_t}$	.83	41.21
	(1.79) (.347) (.311) (10.3)		
	$P_{C_{t+1}} = 19.7 + .755P_{C_t} - .254P_{C_{t-1}} + V_{3_t}$	.34	6.6
	(2.25) (3.38) (1.17)		
2LS	$Q_t = 410 - 8.22P_{C_t} + 4.62P_{C_{t+1}} + 351I_t + V_{1_t}$	.84	44.77
	(4.30) (3.02) (1.21) (11.8)		
	$Q_t = 449 + 11.1P_{C_t} - 10.2P_{f_t} + .728Q_{t-1} + V_{2_t}$	.66	16.02
	(2.21) (1.74) (1.93) (4.98)		
	$P_{C_{t+1}} + 16.9 + .909P_{C_t} - .351P_{C_{t-1}} + V_{3_t}$	.32	6.25
	(1.86) (3.49) (1.50)		
3LS	$Q_t = 426 - 8.14P_{C_t} + 4.30P_{C_{t+1}} + 349I_t + V_{1_t}$	.85	-
	(4.47) (3.36) (1.21) (15.6)		
	$Q_t = 192 + 8.76P_{C_t} - 7.36P_{f_t} + .888Q_{t-1} + V_{2_t}$	.70	-
	(.721) (1.49) (1.43) (5.00)		
	$P_{C_{t+1}} = 18.7 + .873P_{C_t} - .348P_{C_{t-1}} + V_{3_t}$	.33	-
	(1.95) (3.34) (1.58)		
	n = 29		

c) OLS Estimation

The demand equation and its coefficients are very significant and these results could be seen as a very satisfying demand curve estimation. But the sign of the cocoa price coefficient in the supply is not satisfactory nor is the coefficient significant. This could indicate serious simultaneity bias in the system.

d) 2LS Estimation

These results are more in line with economic theory than the previous ones, especially the supply function where the cocoa price coefficient's sign changed for the better. The significance of the price coefficients of this equation increased while the other coefficients of this model remained significant. The demand equation also underwent favorable change. It seems, indeed, more logical for the direct price coefficient to be absolutely greater than the expected price's.

One should already be convinced that this model estimated by OLS will produce severe simultaneity bias. R^2 loose their meaning using 2LS because the estimated error is not orthogonal to the estimated left hand variables; however, a high R^2 still indicates a good fit which is a very positive feature if one is interrested in forecasting.

As explained above, the lack of serial autocorrelation in the expectation equation is essential to the theoretical soundness of the model. The Durbin Watson statistic cannot be used in such dynamic simultaneous systems. Godfrey [1976] developed a test that enables us to estimate serial autocorrelation:

$$e = \rho e_{-1} + u$$

where: u is independently normally distributed;
e is the equation's error term;
ρ is the autoregressive parameter.

Under the hyrothesis $\rho = 0$, the Godfrey's Π^2 statistic is a central χ^2_1 variable. Its value in the expectation equation is of:

$$\Pi^2 = 1.458 ,$$

implying that we cannot reject the null hypothesis at a 20% significance level.

e) 3LS Estimation

Here again the bulk of the change is carried by the supply equation. The 2LS parameters are, as we know, not as asymptotically efficient as the 3LS parameters. But here, the results must be read in light of the size of the sample. A 3LS estimation requires the variance covariance matrix of the error terms which adds 6 parameters to the estimation. In order to decide whether the 3LS method is needed the value of these estimates must be considered. The correlation matrix of the residuals from the 2SLS equations is presented here:

$$\begin{vmatrix} 1 & .236 & -.639 \\ & 1 & .227 \\ & & 1 \end{vmatrix}$$

It seems that the correlation coefficients are fairly large and should not be ignored.

f) Discussion

From the OLS results it appears that the supply function is least defined, and this was confirmed by the changes due to the alternative methods. The parameters of the demand function, however, also underwent change, especially from the first stage to the second. But it is clear that the choice lies between the second or third stages estimations since simultaneity bias was strongly established.

In the 2LS estimation the supply coefficients are much higher than the demand coefficients, indicating that in some sense producers have more choices than consumers. This goes against preconceived ideas of the magnitude of SR supply response of an orchard product which is thought to be weak. This is more so in countries where there are not many alternatives open to the producers, as is the case in cocoa producing countries. Also one may think of cocoa as a luxury product and as such expect a high demand elasticity.

ECONOMIC RESULTS

a) Description

The results of the 3LS estimation yield the following elasticities: (Calculated at the mean)

Demand (short term)	
Price	-.30
Expected Price	.16
Income	.77
Supply	
Price (short term)	.33
Coffee Price(short term)	-.37
Price (long term)	2.95

b) The Demand

The price elasticities of demand are short term elasticities. The income variable is supposed to account for the trend.

It is of interest to compare our results with the results obtained in other works:

Reference	Price Elasticity	Income Elasticity	Remark
Behrman, 1965	-.18 to .02	-1.58 to .53	5 consuming countries
Akiyama et al.,1981	-.120	.34	N. America
" " " "	-.135	.35	W. Europe

Behrman's results indicate a very wide range for income elasticity, and a weak and not significant price elasticity. Thus, they seem to be inconclusive. In both works stock equations were estimated, where unground cocoa was a proxy for stock change. As already explained this seems mistaken. In their specification, Akiyama and Duncan did introduce trend factors such as the year, which was not the case here. Their income elasticity should, therefore, be a better estimate for the short term. It is argued here that the effects of trend factors such as intervention, technological change etc. are always linked to the variable that is most correlated with the trend, in our case income, and that the estimates obtained for the short term income elasticity in this research are therefore biased.

c) The Supply

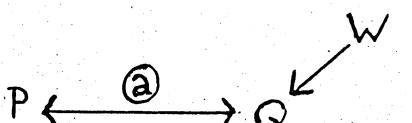
The short term price coefficients are the only ones of interest since the long term coefficient is biased for the reason stated above. The short term elasticity of cocoa is caused by better care of the orchard which can immediately raise production, such as weed control, and is the result of the harvesting of old trees, which are not worthwhile harvesting when prices are low.

Other estimates were found in the litterature:

Price elasticities

Area	Short term	Long term	Reference
Ghana	0	.4 - .87	[Bateman, 1965]
World	.138	.42	[Akiyama et al.,1981]
Ivory Coast	.259	.32	- " -

All these results are based on very similar specifications, with the lagged supply on the right hand side. The main difference lies in the fact that the model presented here uses a minimal amount of variables while the others are rather exhaustive. The question is of course to decide whether one model is under - or the other one overspecified, but the question is also on another level, as the following theoretical example will show:



Let, for instance, P be the price, Q the production, F the fertilizer use, W the weather and R the production of rice. Arrows indicate causal relationships while a broken arrow indicates an accidental correlation. The problem is to estimate the effect of the price on quantity. In this case, to include R would be overspecification while the omit W would be underspecification, and will bias the results whenever $\rho_{PW} \neq 0$. But in the case of high multicolinearity between W and Q, $\rho \approx 1$, the bias due to underspecification may be negligible as compared to the high variance of the estimates when W is introduced. The

inclusion or omission of F give two different answers about the effect of P on Q. When F is included the measured effect of P will be (a) while if F is ommited this effect becomes (a) + (b) . (c) . [1] This example shows that this question should not be only answered according to statistical or economical right. Both give correct answers. In one case the estimate is the total derivative and in the other the partial derivatives. Note that in this case F must be included with due care for the simultaneity of the action of P on F and Q ; if this is not accounted for the results will be biased.

The purpose of this research is to define the total effect of the price on quantity and the effect of P is expressed through intensification which includes, among other things, more fertilizers. Thus F should not be included in the supply equation.

CONCLUSION

The reader should recall the Cobweb nature of the model and note that the cocoa price slopes of supply and demand are almost equal. In a Cobweb model it means that the equilibrium is never reached. Akiyama and Duncan state that the world price of cocoa behaves in a cyclical manner "because of the low price elasticities of supply and demand and relatively long adjustment lags". These findings could provide yet another reason.

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[1] This is true only when variables are standardized, but it explains well the nature of the problem. For more details, see [Li, 1977].

As all findings they were obtained at a price that should not be ignored. 1) As mentionned before, no long term effects are estimated and the evolution of time will certainly create new conditions which will change the parameters, but this is true of all empirical works; 2) More important is that cocoa is not a competitive market but it was specified as such. The reason for this lack of competition is the existence of large producers and consumers and at times of an International Cocoa Agreement. No explicit or implicit reference to this fact was made here. 3) The aggregation level was very high. For instance the cocoa price of the commodity exchange was used although no producer nor consumer pays this specific price. This could create a bias, and it is most acute on the supply side where the planters are more affected by government policy. But it can be argued that governments look at this exchange price to decide on their policy. 4) The model was here estimated by least square methods and is overidentified. Whenever this is the case, the results will depend on which endogeneous variable was chosen as left-hand-side variable. Maddala's advice was followed here [Maddala, 1977] and the left-hand-side variable was chosen according to our understanding of the economic relationships. 5) Last but not least, the expectation equation. It is totally arbitrary but this is unavoidable. While supply and demand try to estimate links between facts that happened and are more or less concrete, expectations never leave the realm of thoughts and are never fully developed, not even the minds of the economic agents. The simplification done here might prove wrong, but no method can pretend to be right.

DATA BASE

Period: 1950 - 1980

Cocoa Price[a : Ghana (London) in US ¢/pound: NP_{C_t}

Coffee Price[a : Brazil (New York) in US ¢/pound: NP_{f_t}

Quantity: Net World Crop[b in Tons : Q_t

US income[a in 10^9 $ USI_t

UK income[a in 10^9 £ UKI_t

Germany's income[a in 10^9 DM GI_t

UK-US exchange rate[a in $/£ $USUKE_t$

Germany-US exchange rate[a in DM/$ $GUSE_t$

US population[a in 10^6 hab. USP_t

UK " 10^6 UKP_t

Germany's " 10^6 GP_t

US consumer price index[a 1977 = 100 $USIC_t$

$$P_{C_t} = NP_{C_t} * 100/USIC_T$$

$$P_{f_t} = NP_{f_t} * 100/USIC_T$$

$$I_t = 100*(.45*USI_t/USP_t + .2*UKI_t*USUKE_t/UKP_t + .356*GI_t/GP_t*GUSE_t)/USIC_t$$

Sources:

(a International Financial Statistics, IMF Year book, 1979, 1980.

(b Cocoa Statistics, Gill and Duffus, 1981.

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