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Price Stabilization Policies in World Markets for Primary Commodities: An Application to Cocoa[1]

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The desirability of reducing the amplitude and frequency of price fluctuations in world markets for primary commodities has been stressed for a long time. However, it has to be recognized that little progress has been made since the adoption of the Havana Charter a quarter of a century ago. This lack of progress partly reflects our limited understanding of the mechanism of price fluctuations.

The examination of postwar data suggests that price variations often result from the combination of three components: first, a long-term trend; second, medium-term fluctuations with some kind of periodicity; and third, purely random disturbances. This type of price behavior, which is observed in a time series, can only be generated by a commodity model which is both dynamic and stochastic. The dynamic element reflects simultaneously time lags in the demand and supply responses to price changes and the impact on current prices of the level of the stocks already accumulated. The stochastic elements reflects random disturbances in the structural equations.

The first section briefly analyzes the price behavior generated by a theoretical model with linear relationships between quantities and prices. The second section analyzes such a model, after releasing the linear assumptions, when applied to the world cocoa market. The third section summarizes the findings of policy simulations on the basis of the cocoa model.

1. *Linear price model*

A world commodity model can be expressed most simply by four equations. The first characterizes the world demand for consumption; the second shows the world supply from current production; the third illustrates the world demand for stocks; the fourth is a market clearing identity. The three structural equations can be expressed as linear functions of exogenous vari-

1 This paper is based on work carried out by the author while at the International Bank for Reconstruction and Development. These views, however, are solely the responsibility of the author and should not be interpreted as representing the official opinion of the International Bank for Reconstruction and Development. The author wishes to acknowledge the helpful suggestions of Mr J. K. Sengupta and the assistance of Miss P. Davis, who performed the statistical work and Mr B. Krishna, who prepared the computer program for the simulations.

ables and of prices lagged from 'zero' to 'k' years. By solving such a model, prices can be expressed in the form of two components:

(1) $P_t = \overline{P}_t + x_t$

The first component, $\overline{P}_t$, is a linear combination of only exogenous variables. The second, x_t, is an autoregressive process defined by:

$$(2) \quad \sum_{j=O}^{j=k} b_j \; x_{t-j} = e_t$$

The parameters, b_j, of the autoregressive process, x_t, are linear combinations of the parameters in each of the three structural equations, which characterize the quantity response to prices lagged 'j' years. Similarly, the error term, e_t, is a linear combination of the error terms of the three structural equations. In the absence of serial correlation, the degree of the autoregressive process, x_t, is equal to the maximum lag in the quantity response to prices for any of the three structural equations.

Let us consider first the component, $\overline{P}_t$. In the demand function, the main exogenous variables are often population and income. They generally follow a fairly regular time trend. In the supply equation, technological progress is sometimes considered as 'disembodied' and expressed in the form of a time trend. In the stock function, the impact of exogenous variables is small in the long-term. Consequently, the first component, $\overline{P}_t$, in equation (1) can often be expressed as a simple expression of time, t, and be assimilated to the long-term price trend.

Let us turn now to the second component, x_t, which is superimposed on the trend, $\overline{P}_t$. We have to consider the nature of the lagged responses to prices in the three structural equations. For stocks, the change in inventories, $S_t - S_{t-1}$, is generally related to the difference between anticipated and present prices. The stock function therefore automatically introduces a lag, but this lag may be limited to one year. For consumption, the lag may go from one to three years, since demand does not generally fully adjust itself to price changes during the current year. For agricultural production, there is always a lag and its importance may be very great. The production response to price changes is generally small in the short-term but large in the long-term Consequently, the second component, x_t, of the price equation (1) is as a rule an autoregressive process of the type (2). The degree 'k' of this autoregressive process corresponds to the maximum lag of the production response to prices. The autoregressive process, x_t, therefore generates medium-term fluctuations with some kind of periodicity on which are added yearly random fluctuations.

Given the variance of the purely random disturbances, e_t:

(3) $E(e_t^2) = s^2 \quad E(e_t) = E(e_t, e_{t-\tau}) = 0$ for $\tau \neq t$

the nature of the autoregressive process, x_t, depends on the roots of the characteristic equation:

$$(4) \quad \sum_{j=O}^{j=k} b_j \; y^{k-j} = O$$

If the modules of all the roots of equation (4) are smaller than unity, the process, x_t, is stationary. Otherwise, the process is explosive.

If the process, x_t, is stationary, it can be expressed in the form of two components:

(5) $x_t = \hat{x}_t + e_{pt}$

The first component, $\hat{x}_t$, is the part of x_t which can be forecasted on the basis of the backward linkages of equation (2). The second component, e_{pt}, is the random price variation reflecting the genuine random disturbance, e_t, which is expressed in terms of quantities. The economic significance of the autoregressive process depends on the ratio between the variance of the predictable component, $\hat{x}_t$, and that of the unpredictable component, e_{pt}.

In the normal case of multiple lags, the periodicity of the autoregressive process has to be studied by spectrum analysis. The economic significance of the autoregressive process can be illustrated in the case of a single lag, since the nature of the problem remains basically the same in the case of multiple lags. We shall therefore limit ourselves below to the case of a single lag (k = 1). The characteristic equation (4) has then a single root which can be written:

$$\beta = -\frac{b_1}{b_0}$$

For $|\beta| < 1$,

$$\text{Variance } (x_t) = \frac{\text{variance } (e_{pt})}{1 - \beta^2}$$

$$\text{Variance } (\hat{x}_t) = \beta^{2t} \text{ variance } (x_t)$$

Consequently, if $|\beta|$ is small, say smaller than one-third, the lag does not significantly affect the price behavior. In first approximation, the component, $\hat{x}_t$, can be ignored and the price, P_t, can be taken as fluctuating randomly around the price trend, $\overline{P}_t$. On the other hand, if $|\beta|$ is large, the autoregressive process is essential to the understanding of price variations. Thus, for $|\beta| = \cdot 95$, the variance of the price deviations from the trend, $\overline{P}_t$, is ten times larger than the variance of e_{pt}, which characterizes the sole impact of genuine random disturbances. The forecasting power of the recursive system is excellent, provided of course the model is correctly specified. If $|\beta|$ reaches or exceeds unity, the model is misspecified since prices cannot become negative in the true world. Linear relations between quantities and prices are acceptable only within a limited range. When prices fall outside this range, the quantity response to price does not remain constant. In particular, production stops altogether before prices reach zero.

II. *Non-linear price model: an application to cocoa*

A linear model did not give very good results when applied to cocoa. The long-term production response to prices lagged about 12 years tended to be higher than the combined short-term supply and demand responses. This led to an unstable model. To avoid explosion of the model, constraints can be introduced following Forrester's method. The solution adopted here was to relax the linearity constraint. However, before analyzing the non-linearity of the production function, it is necessary to define the price series.

Price series

Price was referred to above as if consumers, producers and speculators reacted to the same price. Since this is not the case, four deflated yearly price series were used: spot New York, average export unit-value, and producer prices in Ghana and Nigeria. As shown in Table I, all these price series are closely correlated, provided the appropriate lags are used. The very close fit between the spot (average unweighted) and the average export unit-value is not surprising, nor the fact that the latter lags slightly in relation to the former. But the close fit between world and producer prices in Ghana, and especially in Nigeria, is worth noting. It shows that, after a few years, producer prices adjust themselves fairly closely to the evolution of world prices. For this reason the adjustment of the production function in Ghana and Nigeria was almost as good with world prices as with producer prices.

Table I: Cocoa : relation between annual deflated price series 1950–67

P_{Nt} = Spot price, New York (US cents per pound)

P_t = Average export unit-value (US cents per pound)

P_{gt} = Producer price, Ghana (US cents per pound)

P_{nt} = Producer price, Nigeria (US cents per pound)

P'_{gt}, P'_{nt}, P'_t = three year moving averages of price series

(Between parentheses are the standard errors of estimation for the dependent variable and t ratio for the independent variables).

						$\bar{R}^2$	d
P_t (1.39)	=	$.69005 P_{Nt}$ (20.4)	$+ .19403 P_{Nt-1}$ (5.7)			.976	2.45
P_{gt} (1.80)	=	5.575 (13.2)	$+ .12501 P_t$ (2.1)	$+ .10809 P_{t-1}$ (1.6)	$+ .07170 P_{t-2}$ (1.2)	.58	1.35
P'_{gt} (.82)	=	4.147 (20.9)	$+ .13514 P'_t$ (3.6)	$+ .21923 P'_{t-2}$ (5.0)		.88	1.42
P_{nt} (1.48)	=	−2.33298 (6.7)	$+ .18700 P_t$ (3.8)	$+ .30021 P_{t-1}$ (5.2)	$+ .15187 P_{t-2}$ (3.1)	.991	1.12
P'_{nt} (1.23)	=	−2.7509 (9.3)	$+ .31687 P'_t$ (5.6)	$+ .33616 P'_{t-2}$ (5.1)		.918	.799

In the world model, world average export unit-value was used as the price indicator for the supply function as well as for the demand functions. For the stock function, the spot price New York was used as the price indicator. A price equation transforming the spot price into world export unit-value with the appropriate lags was therefore introduced into the model.

Non-linearity of the supply response

Cocoa production in year 't' is a function of two factors. The first is the capacity existing in year 't' which depends on the tree population of bearing age (say between 6 and 50). The second is the rate of utilization of the capacity, which is affected by the frequency of picking and by the application of purchased inputs such as fertilizers and pesticides. The impact of prices on capacity creation corresponds to the long-term supply elasticity. The impact of prices on the rate of capacity utilization corresponds to the short-term supply elasticity.

Let us consider first the short-term elasticity. When prices fall sharply, the rate of capacity utilization also falls. Since it is always possible not to use existing capacity, supply will always disappear before prices reach zero. When prices rise, the rate of capacity utilization increases up to a point. But once the capacity is fully used, supply cannot respond in the short-term to any further rise in prices. The short-term supply response to price changes is therefore asymmetrical. This applies not only to tree crops, such as coffee and cocoa, but also to minerals, such as copper and tin. To reflect this asymmetry, the short-term price response was expressed in the form of $\frac{b}{P^2_{t-1}}$.

Let us now turn to the long-term elasticity. Let us assume that capacity increases by 3 per cent a year at a price of 30. When the price reaches 40, planting will increase and capacity will rise rapidly. When the price falls to 20, the cultivator will probably abstain from planting new trees. He will probably also give little care to the trees already planted, but he will not generally uproot them. He will rather wait for better years to come. To reflect this asymmetry, the rate of growth of capacity in year 't' was related to the square of the price in year 't–τ". During this century, such a relation appeared remarkably stable, as shown by the 't' ratio for parameter b in equation (6) below.

$$(6)\ \log \frac{C_t}{C_{t-1}} - x_t = \underset{(.85)}{.00151} + \underset{(6.8)}{.000\ 01881}\ P^2_{t-\tau} \qquad d = 2.3$$

with C_t = three-year moving average of world cocoa production.
P_t = average world import unit-value deflated.
t = 1907 to 1966
τ = gestation lag: 7 from 1907 to 1960 and 6 after 1960

x_t = dummy variable for World War II: −.0201 from 1939 to 1943; + .0201 from 1946 to 1950; 0 for all other years.

The absolute increase in capacity can also be written in the form:

$$(6') \quad C_{\Theta+\tau} - C_{\Theta+\tau-1} = b\,(P_\Theta^2 - \pi^2)\, C_{\Theta+\tau-2}$$

where π is the stationary price at which capacity would remain stable. $C_{\theta+\tau-2}$ is used instead of $C_{\theta+\tau-.5}$, because only the former is known in year $\theta + \tau$. Production Q_t in year t can thus be expressed as:

$$(7) \quad Q_t = a + b \sum_{\Theta=1-\tau}^{\Theta=t-\tau} (P_\Theta^2 - \pi^2)\, C_{\Theta+\tau-2} - \frac{b\, C_{t-2}}{P_{t-1}^2}$$

Such a function fits very well for both periods before and after World War II. As shown by equation (13) in Table II, 91 per cent of the variance of world production in the postwar period was explained by the long– and short-term responses to prices.

In the case of Ghana, it was possible to measure the long-term response reflecting the impact of prices on plantings separately from the short- or medium-term response reflecting the impact of pesticides. With I_t standing for pesticide application in year 't', the regression equation was:

$$(7) \quad \log Q_{gt} = \underset{(133.0)}{2.39733} + \underset{(1.6)}{.000\,000\,089}\, P_t^* + \underset{(1.6)}{.03613} \log I_{t-1} + \underset{(1.9)}{.04144} \log I_{t-2}$$

$$\bar{R}^2 = .908 \qquad d = 3.2$$

To reduce the intercorrelation between the explanatory variables, the impact of pesticides on cocoa production, IQ_t, has been calculated by applying production yardsticks measured from agricultural experiments. The formula used was:

$$IQ_t = 150\, I_{t-1} + 200\, I_{t-2} + 50\, I_{t-3} + 50\, I_{t-4}$$

Introducing the impact of pesticides, IQ_t, thus calculated, as an explanatory variable in the production equation led to the following regression:

$$(7'') \quad Q_{gt} = \underset{(20.9)}{260.90527} + \underset{(3.6)}{.000\,11}\, P_t^* + \underset{(2.6)}{.60483}\, IQ_t$$

$$\bar{R}^2 = .880 \qquad d = 2.6$$

The regression coefficient of .6 for IQ_t suggests that at the national level the average impact of pesticide in Ghana was lower than the one calculated from the production yardsticks based on agricultural experiments. But the most interesting finding is probably the close relation between pesticide application, I_t, and Ghana's producer price, P_{gt}, as well as the high level of implied price elasticity:

$$\text{Log } I_t = -4.45191 + 3.77827 \log P_{gt}$$
$$(4.0)$$
$$\bar{R}^2 = .818$$

When pesticide application is introduced as an explanatory variable, the short-term price response becomes insignificant. This occurs because in the use of pesticide is embodied the short-term production response to prices.

Demand for grindings and stocks

The world demand for grindings, D_t, was disaggregated into three country groups: the demand in developed countries, Dd_t; that in socialist countries, Ds_t; and that in developing countries, Dg_t. During the historical period, the price effect was important for the developed countries and a distinction could clearly be made between the impact of the current year's price and of the previous year's price. These two values of the price elasticity were –.24 and –.18 respectively. For the developing countries, the price effect was lagged one or two years but not very significantly. For the socialist countries, no price effect could be measured.

The demand for stocks is naturally a function of price expectations. For projecting one year ahead, one can use the forecasts of production and grindings regularly published by Gill and Duffus. However, since these forecasts are published less than a year in advance, they cannot be used in a long-term projection model. The simplest stock equation providing a reasonable fit was:

$$\log \frac{S_t}{S_{t-1}} = b \log \frac{P_{Nt}}{P_{Nt-1}}$$

with an elasticity coefficient close to – 1.0.

In year 't', the demand for stocks depends on the spot price, P_{Nt}. The demand for grindings by the developed countries depends on the average export unit-value, P_t. Since P_t is only slightly lagged in relation to P_{Nt}, we are faced with a problem of simultaneous estimation. In view of the difficulty of using multi-stage regressions for non-linear equations, two alternative methods were used. The first was the maximum likelihood method; the second was the instrumental variable method. The forecasts of production and grindings regularly published by Gill and Duffus were used as instrumental variables. Both methods led to coefficients very close to those obtained by ordinary least square regressions.

Solution to the model 1950–67

As appears from the model shown in Table II, the demand for grindings in the socialist and developing countries as well as world supply do not depend on the current price. It is therefore possible to compute $\hat{D}s_t$, $\hat{D}g_t$ and $\hat{Q}_t$ on the basis of the exogenous variables and of the lagged values of the endogenous variables. However, in the case of the demand for grindings in the developed countries as well as of the demand for stocks, it is not possible to compute $\hat{D}d_t$ and $\hat{S}_t$ from values known in year 't–1'. It is only possible to compute $\hat{D}d_{st}$ and $\hat{S}_{st}$ by measuring what would have been the demand in

Table II: Cocoa model, 1950–67

Dd_t	= Consumption of grindings in the developed countries	('000 metric tons)
Ds_t	= Consumption of grindings in the socialist countries	(" " ")
Dg_t	= Consumption of grindings in the developing countries	(" " ")
S_t	= Level of world stocks at the end of year t	(" " ")
Q_t	= World production	(" " ")
Yd_t	= Index of deflated GDP for developed countries	
P_t	= Average export unit-value deflated (US cents per pound)	
P_{Nt}	= Spot, New York (" ")	
P_t^*	$= \sum_{\theta=1-\tau}^{\theta=t-\tau} (P_\theta^2 - \pi^2) C_\theta + \tau - 2$	
X,Y,Z	= Dummy variables in the stock function	
C_t	$= 1/3\ (Q_{t-1} + Q_t + Q_{t+1})$	

(8) $\log Dd_t = 2.8013 + .3274 \log Yd_t - .4182 \log P_t + .1817 \log \dfrac{P_t}{P_{t-1}} + \epsilon_{dt}$

(.0137) (865.78) (5.73) (9.58) (5.01)

(s.e.e.) (t ratio)

$\bar{R}^2$=.969 d=1.63

(9) $\log Ds_t = .763 + .06361t + .2760 \log P_{t-1} + \epsilon_{st}$ .994 1.541

(.0245) (132.) (43.33) (4.62)

(10) $Dg_t = 175.86 + 6.848t - 2.836 \dfrac{P_{t-1} + P_{t-2}}{2} + \epsilon_{gt}$ .853 2.24

(22.07) (33.81) (5.20) (3.16)

(11) $\log \dfrac{S_t}{S_{t-1}} = .03909 - .88070 \log \dfrac{P_N}{P_{Nt-1}} - .00312t + .18087X + .21192Y$

(.01714) (9.7) (19.35) (3.8) (10.5) (12.1)

$+ .19826Z + \epsilon_{\sigma t}$ $\bar{R}^2$=.969 d=1.58

(6.2)

(12) $P_t = .69005P_{Nt} + .19403P_{Nt-1} + \epsilon_{pt}$ .976 2.45

(1.39) (20.4) (5.7)

(13) $\log Q_t = 2.9025 + .000\,000\,03394\, P_t^* - 17.21 \dfrac{1}{P_{t-1}^2} + \epsilon_{qt}$ .911 3.149

(.03106) (396.5) (9.2) (1.3) Π=22.0

(13') $\epsilon_{qt} = -.5890\ \epsilon_{qt-1} + \epsilon_{qt}^*$ .343 2.31

(14) $-Q_t + Dd_t + Ds_t + Dg_t + .\Delta S_t \equiv 0$

year 't', if prices had remained stable from year 't−1' to year 't'. Therefore by assuming that $P_{Nt} = P_{Nt-1}$, the surplus demand at last year's price is given by:

$$\hat{F}_t = \hat{Q}_t + \hat{D}d_{st} + \hat{D}s_{st} + \hat{D}g_{st} + \hat{\Delta}S_{st}$$

This surplus demand in year 't' at prices, P_{Nt-1}, is cleared through changes in the grindings of developed countries and in the level of stocks. The relative price variation, $z = \dfrac{P_{Nt} - P_{Nt-1}}{P_{Nt-1}}$ needed to clear the market depends on the current year's demand elasticities for grindings and stocks, b_{do} and $b_{\sigma o}$, respectively. This is illustrated by the clearing equation (15) which was solved by a Taylor series.

$$(15)\quad \hat{F}_t + \hat{D}d_{st}\left[A_t\ (1+z_t)^{b_{do}} - 1\right] + \hat{S}_{st}\left[(1+z_t)^{b_{\sigma o}} - 1\right] = 0$$

with b_{do} = price elasticity of the demand for grindings in the current year.

$b_{\sigma o}$ = price elasticity of the demand for stocks in the current year.

$$A_t = \left[\frac{1}{.88408} \quad \frac{P_{t-1}}{P_{Nt-1}}\right] - b_{do} \text{ known in year t.}$$

After appropriate transformations, the error terms, ϵ_t in each of the structural equations were expressed in terms of quantities, e_t. By combining these, the surplus demand, e_t, generated exclusively by random disturbances, was obtained as follows:

$$e_t = -e_{qt} + e_{dt} + e_{st} + e_{gt} + e_{\sigma t} + e_{pt}$$

In year 't', the surplus demand at the previous year's price consists of two parts: F_t, which is explained by exogenous variables and backward linkages and therefore liable to forecasting; and e_t, which is generated by random disturbances in year 't' and therefore not liable to forecasting. Solving equation (15) from the known prices in year 't–1' and before gives the forecasted price change from year 't–1' to year 't'. Solving equation (15) by adding e_t to F_t gives the actual price change from year 't–1' to year 't'. This is a way to test the accuracy of the computation program.

The simulation of a one year price forecast was made by solving the model for the year 1950 from actual values for 1949 and earlier; then for 1951 from actual values for 1950 and earlier; and so on for 1952 and later years. As shown in Figure I, three types of projections were made. First, it was assumed that the error term, e_q, was known from a perfect production forecast ($e_t = e_{qt}$). Second, it was assumed that none of the error terms were known ($e_t = 0$). Third, it was assumed that neither the error terms nor the values of the dummy variables in the stock function were known ($e_t = X = Y = Z = 0$). It can be seen that, even in the latter case, the model performed well.

The simulation of a long-term forecast was made by assuming all the error terms were unknown from 1950–1967. Thus, the projections for the year 1950 are based on the actual values in 1949 and earlier. The projections for 1951 are based on the projections for 1950 and the actual values in 1949 and before. Finally, the projections for 1967 are based on the projected values from 1966 to 1950 and actual values for 1949 and before. As appears from Figure II, the model performed very well, even when suppressing the dummy variables in the stock equation. This stresses the importance of long-term linkages.

Projections 1968–2000

The purpose of the projection exercise was not to forecast prices in the year 2000. First, it was to test the stability of the model both to various changes in the structural parameters and to random disturbances generated by the Monte Carlo technique. Second, it was to compare the efficiency and robustness of various intervention rules aiming at increasing the discounted flow of earnings and reducing the instability of prices and earnings.

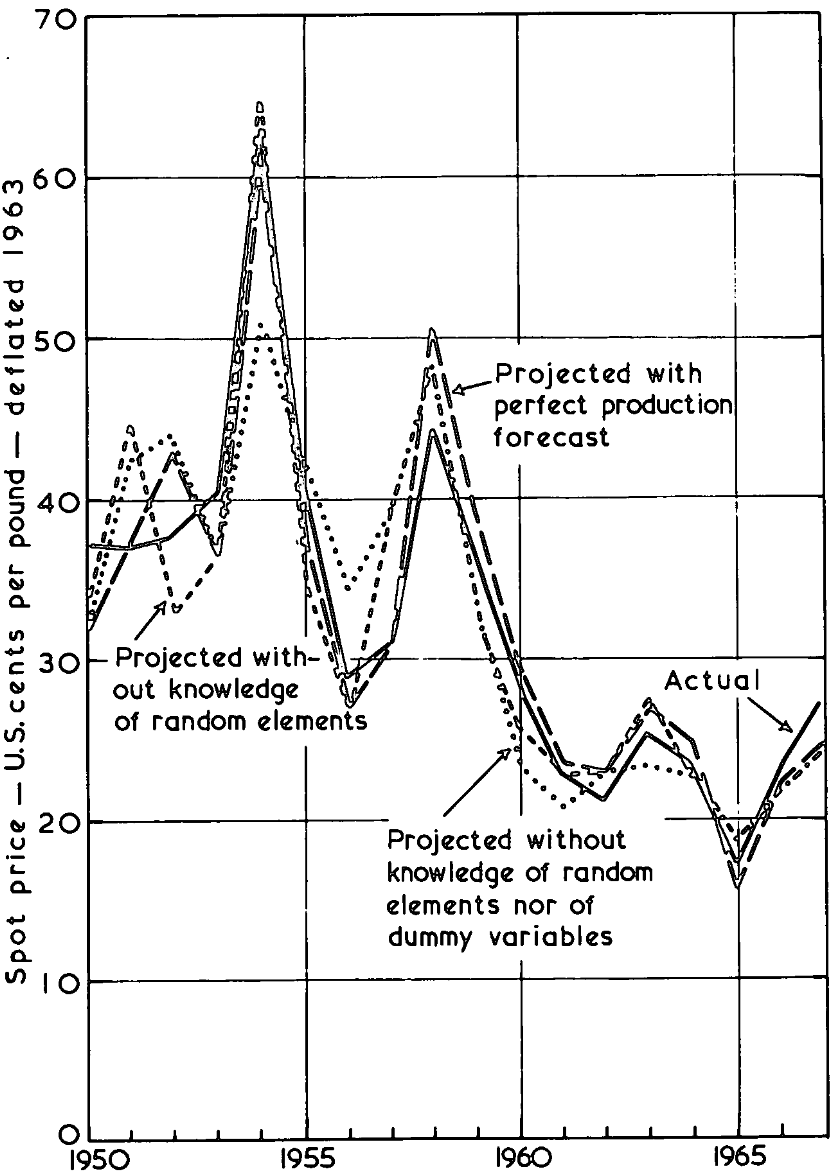

Figure 1. Short-term price simulation forecast, 1950–1967.

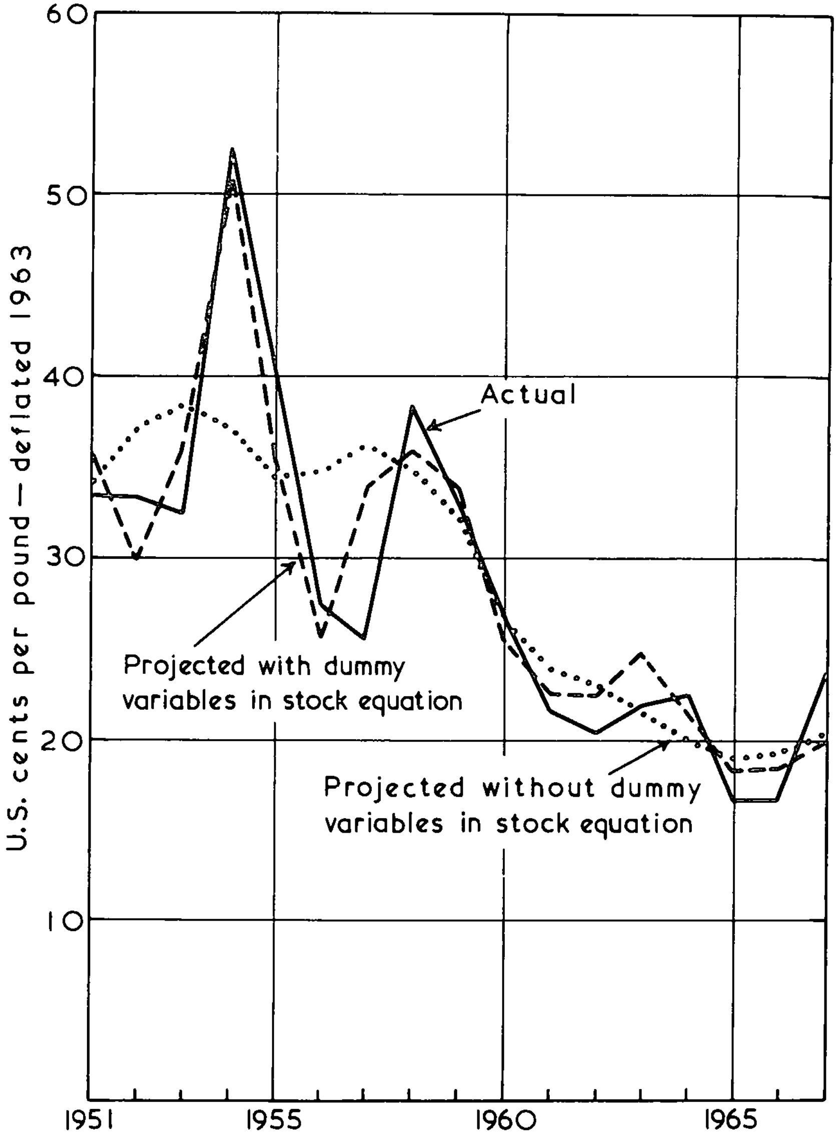

Figure 2. Long-term simulation forecast, 1951–1967; world export unit value estimated from 1950 with and without dummy variables.

Regarding the parameters of the structural equations, three variants were selected for the growth of demand in the socialist countries, two for demand in developing countries and five for supply. Regarding the disturbances, random numbers were generated for 33 years for each of the seven structural equations. These random numbers were assumed to be independent[2] of each other and normally distributed with zero mean and a standard deviation equal to that measured between 1950 and 1967. The errors were generated from logarithmic equations in order that their absolute value would increase proportionately to the size of the variables; otherwise, the error terms would have been too small in the year 2000. The generation of the $33 \times 7 = 231$ random numbers was repeated 25 times, so as to base the simulation on 25 random samples.

Two conclusions emerge from these experiments. First, the model appears basically stable; in no case did it explode. Second, the long-term cycle is not due to an autoregressive process of random disturbances, since the average price path for the 25 samples does not substantially differ from the price projected in the absence of random disturbances. In both cases, the long-term cycle is very markedly amortized after 1980.

The origin of the postwar cocoa cycle was the downward shift of the world demand curve from 1931 to 1946; this reflected both the great depression and the closure of the market in continental Europe during the war. During this fifteen-year period, deflated prices fell, on the average, to 12 cents per pound, compared with 25 cents, on the average, between 1900 and 1967. Because cocoa prices were consistently depressed from 1931 to 1946, the world cocoa capacity was no higher at the end of the war than at the beginning of the great depression. Postwar recovery boosted demand and prices shot up during the fifties. These high prices induced a large increase in capacity which came into production around 1960. Due to the gestation lag, capacity overshot demand and prices fell from 1960 to 1967. This in turn induced a brake on capacity expansion after 1960. The latter was largely responsible for the 1968–69 price boom.

III. *Policy simulations*

The policy objectives were to increase the discounted value of export earnings and to reduce the fluctuations[3] of price and earnings. The policy instruments were of four types[4]: first, modifying output through appropriate production policies; second, expanding demand through disposal of surpluses to non-competing uses; third, disassociating producer from consumer prices through export taxes or import levies; fourth, modifying inventories through international buffer stock operations.

2 For the 1950–67 period, covariance between the error terms was small.

3 Measured by the variance from a linear trend.

4 To simulate the application of export quotas, it would be necessary to disaggregate the world's supply function among the various producing countries. With an aggregated supply function, the implementation of an overall quota would ultimately result in a combination of the four instruments listed.

Production policies

Inasmuch as the cycle is primarily generated by the time-phasing of planting, appropriate changes in the time-phasing would be the most obvious way of modifying the cycle. The countercyclical policy to be applied would consist of curtailing new plantings during price booms and promoting rehabilitation schemes during depressions. These policies would have to be based on long-term forecasts and the difficulty in successfully implementing such policies is their high sensitivity to errors in long-term forecasts. Nevertheless, a model would be useful at least to avoid the most obvious errors: such as the tendency of a number of agencies to place a ban on investment projects during the price trough, to resume lending when the price has recovered and to push lending during the price peak. Such practices only aggravate cyclical instability.

Another way of dampening the long-term cycle, less demanding in terms of forecasting abilities, would consist of increasing the medium-term response to prices by modifying the level of application of current inputs, fertilizers and pesticides in particular. With good long-term forecasting techniques, this method would be less efficient than the previous one. But in the absence of good long-term forecasting techniques, it would provide a way of correcting errors already made in the time-phasing of plantings.

Pesticide applications were started in the late fifties, but fertilizer applications are just starting to be more widely used now. If the use of pesticides and fertilizers for cocoa is to expand in the seventies and if the level of application is sensitive to cocoa prices, as was earlier illustrated with the case of pesticides in Ghana during the last 12 years, the long-term cocoa cycle could disappear. This is illustrated by one of the supply functions simulated, as shown in Figure III. In this variant, a medium-term response with a two and three-year lag, reflecting the price impact of pesticides and fertilizers on production, was added to the short-term production response lagged one year.

Diversion sales

During a price trough, an agency acting on behalf of the exporting countries could buy part of the supply at market prices and dispose of it at a lower price to non-competing uses, such as the manufacture of margarine. The financial loss of this agency, however, would have to be covered by contributions from the exporters. Provided the disposal did not compete with traditional uses, the exporting countries as a group would always gain from such an operation, even after deducting their contributions to the agency. Due to the low price elasticity of demand, earnings from traditional markets would be higher and the proceeds of the disposal sales would have to be added to it. But in view of the high long-term production response to prices, the cumulated quantities to be disposed of during the trough could be very sizeable. The difficulty would then consist of raising sufficient funds from the exporters to cover the accounting losses of the agency.

Export taxes (or import levies)

In the short-term, the price elasticity of demand is larger than the price elasticity of supply; but the reverse is true in the long-term. Consequently, in the years immediately following the institution of a levy, the producer's price, net of the levy, would be reduced more than the consumer's price, inclusive of the levy, would be increased. Most of the charge of the levy would therefore be initially carried by the producers, while in later years the situation would be reversed. Provided the proceeds of the tax were used in the production of goods other than cocoa, applying a high tax during the peak would mainly tend to reduce producer prices. By curtailing the incentive to increase capacity during the peak, a highly progressive tax would tend to dampen the cycle.

The implementation of fixed, proportional and progressive taxes was simulated over a 33-year period. The results showed that the progressive tax always substantially reduced the amplitude of the long-term fluctuations of prices and earnings, while the fixed and proportional taxes increased it in a number of cases. Moreover, when taking into account the discounted value of export earnings plus tax proceeds, exporting countries were better off with a proportional rather than with a fixed tax, and they were even better off with a progressive than with a proportional tax. Thus, in the model with wide cyclical variations, the net gain of the exporting countries was equal to about 40 per cent of the gross proceeds of the tax in the case of a fixed tax, 50 per cent in the case of a proportional tax and 70 per cent in the case of a progressive tax.

Buffer stock operations

The buffer stock simulation was by far the most complex operation. Before describing the intervention rule, the stabilization objectives of the buffer stock agency have to be defined in relation to the nature of the price variations. As will be recalled from the first section, by combining equations (1) and (5), the price P_t may be decomposed as follows:

$$P_t = \overline{P}_t + x_t = \overline{P}_t + \hat{x}_t + e_{pt}$$

Obviously, the buffer stock agency could not by itself stabilize prices along a trend line, $\overline{P}'_t$, higher than the genuine trend, $\overline{P}_t$, for any length of time. It if attempted to do so, the size of the stocks, N_t, accumulated by the end of year 't', would be expected to increase steadily from year to year and the agency would soon exhaust its financial resources. We shall therefore assume that the objective of the agency is to stabilize prices along the genuine trend $\overline{P}_t$, by fully absorbing the deviations, x_t. If the process x_t is autoregressive of degree 'k' in year zero the agency can forecast the components, $\hat{x}_1, \hat{x}_2, \ldots \hat{x}_k$, and consequently, the expectancy of the accumulated stocks, $\hat{N}_k$, in year 'k'. The actual size of the stocks, N_k, in year 'k' may differ very substantially from the expectancy of stocks, $\hat{N}_k$, calculated in year zero in view of the unpredictable impact of the random disturbances, e_t, during the first 'k' years. However, $\hat{N}_k$ would be the best forecast which could be made in year zero. After year 'k', once the autoregressive process has been eliminated, the agency would only have to absorb the random disturbances, e_t. Thus, from year 'k' onwards the size of the stocks would be expected to follow a random walk. In year zero, the expected level of the stocks to be accumulated in year 'k' + τ' would remain N_k whatever is the value of τ, but the variance of the size of stocks, $N_k + \tau$, would increase proportionately to the number of years, $k + \tau$.

If the agency is confident of its ability to forecast prices many years ahead, it should compute $\hat{N}_k$. Since the cumulated level of stocks can never become negative, the agency should start operations during the trough. It should start precisely when $\hat{N}_k$, the level of stocks expected to be accumulated by the end of the first 'k' years, coincides with N_d, the 'desired level of stocks for cruising'. If $\hat{N}_k$ exceeds N_d, which is usual in the case of medium- or long-term cycles, additional measures, such as production control and surplus disposal, should be implemented during the trough.

Let us assume that the staff of the agency has perfect competence and, consequently uses the right forecasting model. Let us further assume that the agency has luck, in the sense that by the end of the first 'k' years, the random disturbances exactly cancel each other. Under these ideal conditions, the agency would hold by the end of year 'k' the quantity, N_k, precisely equal to the desired level of stocks for cruising. Despite such a perfect start, the agency would not be able to hold the price, $P_{k+\tau}$' to the long-term trend, $\overline{P}_{k+\tau}$' for many years τ. Since the level of stocks, $N_{k+\tau}$' is expected to follow a random walk from N_k, the odds are that the agency would soon find itself either without money or without stocks. In other words, in the absence of unlimited resources, prices cannot be perfectly stabilized through buffer stock operations.

Since mild price fluctuations do not seriously harm consumers and producers, the objective should only be to cushion fluctuations. Once the objective of pegging prices is discarded, the random walk may be avoided by relating the intensity of buffer stock intervention in year 't' to the difference between the level of stocks accumulated by the end of year 't–1' and the 'desired level of stocks'. Since our ability to forecast prices many years in advance is most questionable, it was not attempted to optimize the price path over an infinite horizon. The objective was only to reduce fluctuations from a five-year moving average at low cost. This average was computed on the basis of the actual prices, P_{t-1} and P_{t-2}, and of the forecasted prices, $\hat{P}_t$, $\hat{P}_{t+1}$ and $\hat{P}_{t+2}$.

The results of this simulation exercise were illustrated in relation to a 'desired level of stocks' equal to 4.2 and 6.3 per cent of annual world output respectively. To assess the impact of forecasting ability, it was assumed that in one case the agency used the right forecasting model to project the current price and the next two years' prices, but that in another the agency's forecast for the five-year moving average was simply the average of the prices during the penultimate and antepenultimate years ($.5\ P_{-1} + .5\ P_{t-2}$). As could be expected, the stabilizing effect was greater and the cost lower with the right than with the wrong forecasting model.

The simulation showed that a buffer stock agency operating along this principle would need a large line of credit but, on the average, would draw only a small fraction of this credit. The rate of interest charged on the amounts committed, but undisbursed, is therefore as important as that on the amounts disbursed. In addition to a line of credit, the agency also would normally need the proceeds of an export tax in order to repay its debt. If the agency could repay only when its stocks were gone, the level of the export tax required would remain roughly constant. But if the agency had to repay by a particular date, it would need a higher tax during the initial period of rapid stock accumulation than later when stocks are expected to increase only pari passu with production.

Conclusion

The ways in which prices can be efficiently stabilized depend on our understanding of the mechanism of price fluctuations. The policy models needed should be dynamic and stochastic. However, since the values of the structural parameters are bound to change with time, it is more important to find intervention rules sufficiently robust to errors in the model's specifications than rules which would be optimal only under a particular model's specification. The analysis conducted on the world's cocoa market suggests, inter alia, that more use should be made of progressive export taxes and that a buffer stock agency should not aim at pegging prices between a predetermined floor and ceiling. Such commodity policy models could be useful mainly in pointing the way to avoid mistakes.

SPECIAL GROUP M REPORT

In the discussion of L. Goreaux's paper questions were raised about the use of simple trends to represent long run forces in the model and about the desirability of disaggregating the model (particularly the supply side) into separate country components. It was also pointed out that one of the major difficulties with various stabilization techniques is their dependence on the correctness of the long-term trend forecast while such trends are in fact almost impossible to forecast with any degree of accuracy.

There was also a brief review of recent Soviet experience with demand studies which reported the use of money income and relevant retail prices as the major independent variables. For purposes of forecasting use is also made of budget information collected from a panel of consumers.

L. Goreaux replied to the discussion noting that since production response was dependent on long run prices and since in the longer run all the various cocoa prices moved pretty much together, it was not necessary for the model to distinguish between the various prices and sources of supply. Clearly, however, detailed country studies of supply response would be desirable. He also noted that the virtue of the stabilization rules investigated by him is their robustness to errors of specification in the original model. Since the rules had self-correction components (in the form of feedback based on the discrepancy between actual and desired stock levels) even errors in trend did not cumulate indefinately.

Among the participants in the discussion were: S. Nillson *Sweden,* I. Khrabrov *U.S.S.R.* and O. Gulbrandsen *U.N.C.T.A.D.*