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FORECASTING COTTON PRICES FOR A WIDELY-TRADED STAPLE LENGTH

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I. Introduction

It is Egyptian policy to set a price in dollars at the beginning of the crop year which will apply to export sales throughout the crop year. This technical paper specifies, estimates, and forecasts with alternative models of cotton pricing which should be of use to Egyptian pricing authorities. By offering policy makers alternative models for forecasting the dollar price of $1\frac{1}{16}$" cotton fibers, the paper provides them with pricing information about the most widely traded staple length in international cotton markets. It is hoped that the results will supply not only some of the information needed for that pricing policy, but will also provide insights into the reliability of such forecasted information.

II. A Supply-Demand Approach to the Determination of Cotton Prices

A model of cotton prices will be developed which is based on supply and demand characteristics. The model will include in addition to current cotton production and current processor demand for cotton fibers the effects of expected future production and demand via the supply of storage. Cotton market transactions are often made with a view toward resale at a later date or, in what amounts to the same thing, stocks of cotton are withheld from the market in anticipation of higher future prices. As a result of these speculative transactions, today's price is in large part determined by what tomorrow's price is expected to be. To capture these speculative effects, a cotton pricing equation must reflect the influence of stocks of raw cotton on hand and the effects of future demand and production.

The following set of equations characterize the model of the cotton market.

(1) $Q_t + S_{t-1} = D_t + S_t$

(2) $Q_t = Q(E_{t-1}[P_t], E_{t-1}[A_t], C_{t-1}$

(3) $D_t = D(P_t, Y_t B_t, F_t)$

(4) $E_t[P_{t-1}] = P_t(1 + r_t + s_t - c_t)$

(5) $E_t[Q_{t+1}] + S_t = E_t[D_{t+1}] + E_t[S_{t+1}]$

where Q_t = production available to the market during period t

D_t = processors' demand for cotton fibers during period t

C_{t-1} = cost of producing cotton fibers marketed during period t

S_t = the stock of inventories at the end of period t

P_t = price of cotton fibers during period t

A_t = price of other agricultural commodities during period t

r_t = cost of capital applicable to speculators in cotton fibers during period t

c_t = "convenience yield" associated with holding inventories of cotton fibers during t

B_t = the price of other consumer goods during period t

F_t = the prices of substitutes for cotton fibers during period t

s_t = cost of storage during period t

$E_t[\quad]$ = expectation operator for expectations formed during period t

Y_t = world income

Equation (1) is the equilibrium condition for the cotton fibers market during period t. Total supply available to the market consists of current production, Q_t, and the stock of inventories, S_{t-1}, carried over from the preceding period. Total demand during period t includes D_t, the demand by processors for fiber to be converted into other products, and S_t, the demand for stocks to be carried over to the next period. Equation (2) indicates that production decisions, made during the preceding period, depend on the expected price of cotton fibers at the time they come to market, the expected prices of other agricultural commodities which producers could offer to the market, and the costs of production. End use demand for cotton fibers (see equation (3)) depends on the price of cotton fibers, the income of consumers, the prices of other consumer goods, and the prices of substitutes for cotton fibers. Equation (4) states the condition which underlies the demand for the stock of inventories to be carried over into the next period. This condition, better known as the decision rule for the "supply of storage," suggests that a speculator will accumulate stocks up to the point where the expected future price for the next period is equal to the current price plus appropriate rewards for risk capital, storage facilities, and a convenience yield which compensates for the costs of a stock-out.[1] Equation (5) is the expected market-clearing condition for period t+1 which can -e thought of as the condition which determines $E_t[_{t+1}]$ and thus drives the demand for S_t during the current period.

The equation set (1)-(5) reflects an underdetermined system. Even if S_{t-1}, $E_{t-1}[A_t]$, C_{t-1}, Y_t, B_t, F_t, r_t, s_t and c_t are taken to be predetermined variables or as variables to be determined outside the cotton market, there remain eight variables--Q_t, D_t, S_t, P_t, $E_t[P_{t+1}]$, $E_t[Q_{t+1}]$, $E_t[D_{t+1}]$ and $E_t[S_{t+1}]$-- and only five equations. The problem, of course, is that in a speculative market today's price depends not only on current production and final demand but upon all future expected production and final demands.

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[1]See Michael J. Brennan, "The Supply of Storage", American Economic Review, March 1958, pp. 50-72, for a derivation of this condition and a statement that r, s, and c are best thought of as schedules which depend on other variables, including S_t).

In the model above, which is an example of a "rational expectations" approach to price determination in speculative markets, this is reflected by the inclusion of $E_t[Q_{t+1}]$ and $E_t[D_{t+1}]$, which represents production and final demand in the next period, and $E_t[S_{t+1}]$, which in turn is determined by expected production and final demand in all periods beyond t+1.

If this model of cotton pricing is to be applicable to the real world, a feasible solution to the problem of dealing with production and final demand over many periods must be found. Feasibility usually requires major simplifications. One approach is to ignore entirely the stockbuilding dimension of the problem. In its simplest form this approach restates (1) as $Q_t = D_t$, i.e., stocks are ignored, or, in effect, S_t is assumed to be equal to S_{t-1}. With this assumption, equations (4) and (5) become irrelevant and the system of equations is found to be determined. A second possible approach is to assume that future production, final demands, and end of period inventories are all "normal." In that case S_t becomes a "normal carryover," s_t and c_t are normal, and $E_t[P_{t+1}]$ is related to P_t by the cost of capital, which presumably depends on the expected inflation rate. If the expected inflation rate is assumed to be independent of the cotton market, the system is determinate, making a solution possible. A still more general approach is to assume normality of production, final demand and end-of-period inventories in all periods beyond t+1 while allowing for other patterns for Q_t, $E_t[Q_{t+1}]$ D_t, $E_t[D_{t+1}]$, and S_t. This allows for more general patterns between P_t and $E_t[P_{t+1}]$ while constraining $E_t[P_{t+1+i}]$, $i > 0$, to be consistent with the expected rate of inflation. Of course, other possible solutions to the problem of an underdetermined system exist. It is useful, however, to note that most of the solutions are likely to take the form of simplified assumptions about how price expectations for future periods are formed.

III. Quantifiable Versions of the Model of a Speculative Market

This section identifies alternative approaches to obtaining quantifiable versions of the model described above. As an aid to specifying quantifiable equations, an explicit forecasting horizon relevant to the annual price setting is chosen. Alternative approaches to quantifying the forecasting model are presented and their advantages and disadvantages are considered. The results presented here are compared to forecasting methodologies offered by others.

Consider the forecasting problems of policy makers who choose to set at the beginning of the crop year a price which is to remain fixed throughout the crop year. Since the new crop will be available for marketing in November of December or the new crop year, preliminary forecasts for key internationally traded grades need to be available to policy makers in August or September. While policy makers will surely wish to see updated forecasts before announcing prices (in October or November) for the new crop year, they will find it valuable to have available in August or September a preliminary forecast to use in initial deliberations.

Consider how one might use the model described by equations (1)-(5) in order to generate a forecast of P_t. It will be assumed that the forecaster possesses preliminary data for S_{t-1} and Q_t. The unknowns, in addition to P_t, are D_t, S_t, $E_t[P_{t+1}]$, $E_t[Q_{t+1}]$, $E_t[D_{t+1}]$, $E_t[S_{t+1}]$, etc. The first step to be taken is to assume that beyond some point Q, D, and S assume the kinds of normal patterns identified above. We shall assume that $E_t[S_{t+1}]$ $E_t[Q_{t+2}]$, $E_t[D_{t+2}]$ and all following values are normal and therefore quantifiable based on observable patterns in the past. As a result, there remain six unknowns, --P_t, $E_t[P_{t+1}]$, D_t, S_t, $E_t[Q_{t+1}]$ and $E_t[D_{t+1}]$-- and six equations-- (1), (3), (4), (5) as well as versions of (2) and (3) appropriate for Q_{t+1}

and D_{t+1}. As we shall see somewhat later, this system gives rise to alternative forecasting approaches.

One forecasting alternative is to specify empirical versions of behavioral equations (2) and (3) in terms of current and past variables, estimate the coefficients of these equations, and then use observable values together with (1), (5), and the assumed normal value of $E_t[S_{t+1}]$ to solve sequentially for a forecast of $E_t[P_{t+1}]$. As an example of this one could estimate equation (3) for D_t and substitute into it forecasts of world income, world price levels, and the prices of fiber substitutes for the current year in order to generate a forecast for D_t. This forecast for D_t together with known values of Q_t and S_{t-1} will from equation (1) permit a forecast of S_t, the expected carryover into the next year. In order to forecast Q_{t+1}, one could estimate some version of equation (2) and, upon plugging in observed values of the right hand side variables, generate a forecast for Q_{t+1}. With S_t, Q_{t+1} and S_{t+1} thus qualified one can solve equation (5) for the price which makes D_{t+1} from a version of (3) compatible with the determined values of S_t, Q_{t+1} and S_{t+1}. The resulting forecast of $E_t[P_{t+1}]$ could be used along with values of r_t, s_t, and c_t to calculate P_t from equation (4).

The approach described above required the estimation of a set of structural equations which are then solved recursively to forecast one variable at a time with the forecasted variable becoming an input into the process of forecasting the next dependent variable. Another approach is to solve the system for P_t in terms of observable variables, Q_t, S_{t-1} and forecasted exogenous variables Y_t, B_t, F_t, and A_t. One can estimate this reduced form equation. By substituting observed and forecasted values into the estimated reduced form equation, P_t can be forecasted without calculating values for the other endogenous variables.

It is instructive to compare the alternative approaches set out above to approaches offered by others. Three other studies will be summarized. One is the work presented in F.G. Adams and J.R. Behrman, Econometric Models of World Agricultural Commodity Markets: Cocoa, Coffee, Tea, Wool, Cotton, Sugar, Wheat, Rice (Ballinger Press, 1976). This volume presents the results of the efforts of a group of scholars working under the auspices of the Wharton Econometric Forecasting Unit and Financed by UNCTAD and the Rockefeller Foundation. Forecasts based on these equations are offered periodically by Wharton Econometric Forecasting Associates. A second study to be summarized is that by E.C. Hwa, "Price Determination in Several International Primary Commodity Markets: A Structural Analysis," International Monetary Fund Staff Papers, March, 1979 pp. 157-192 (Vol. 25, No. 1). At the time the study was done, Mr. Hwa was an economist in the Commodities Division of the Research Department of the International Monetary Fund. The third study to be discussed is the work of M.W. French, "Effects of Commodity Price Stabilization: An Econometric Model of the World Cotton Market" (University of Pennsylvania, Ph.D. Dissertation, 1980). This dissertation was prepared under the supervision of F.G. Adams.

The Adams-Behrman (AB) model of commodities markets consists of four equations. The first three equations are similar to equation (1), (2), and (3) above. The fourth equation is identified as a "price determination mechanism (which) takes into account the relationship between available inventory stocks and the level of demand."[2] The price determination equation is specified as

$$(6)\quad \frac{P_t}{B_t} = f\left(\frac{S_t}{D_t}, \frac{S_{t-1}}{D_{t-1}}, \ldots P_{t-1}\right).$$

[2] AB, p. 10.

AB indicate that "this relationship can be rewritten as a demand for inventories relationship which implies that inventories are proportional to the level of demand."[3]

Accepting AB's interpretation of (6) as a stock demand equation allows us to understand how AB solve the problem of today's price as dependent on expected future production and demand. They simply assume away the role of future production and demand by hypothesizing that the stock of inventories does not depend upon $E_t[P_{t+1}]$. Thus $E_t[P_{t+1}]$ does not enter their model. While they recognize that "the costs of holding inventories are not well represented, "they express the hope that "to the extent that the distributed lags in the model are consistent with the formation of expectations in relative price changes, some aspects of speculative inventory behavior may be captured."[4]

Hwa's primary interest is in testing partial adjustment pricing mechanisms and in the role of beginning-of-period inventories on price rather than in forecasting. Nevertheless, it is useful to consider how his model lends itself to forecasting.

Hwa's model is virtually identical to equations (1) - (4) except he states (4) as a desired demand for inventories which may not be equal to the actual end-of-period stock of inventories. Thus Hwa allows for the possibility of market disequilibrium. This leads him to an equation for P_t which, in addition to the variables in equations (1) - (4), includes P_{t-1} as a reflection of the partial adjustment mechanism. Hwa hypotheses that expectations about future prices are given by

$$(7)\quad E_t[P_{t+1}] = \alpha_0 + \alpha_1 B_t + \alpha_2 Y_t + \alpha_3 P_{t-1}.$$

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[3] AB, p. 11.

[4] AB, p. 11.

(While he claims that this is a "rational" hypothesis about the formation of price expectations, he does not demonstrate that such an expected price follows from his pricing model, which it surely does not). After substituting (7) into his model, he derives a partial adjustment theory of current price which takes the form,

$$(8)\quad P_t = b_0 + (b_1 + b_4)D_t - b_4\,(S_{t-1} + Q_t) + b_2B_t - b_3\,\text{TREND} + b_5P_{t-1}.$$

Consider how Hwa's approach could be used for forecasting P_t. A price forecast from (8) requires data for D_t, S_t, Q_t, B_t, TREND and P_{t-1}. TREND VALUES and P_{t-1} are known. Values for S_{t-1} and Q_t are available (at least in preliminary form) from the July issue of Cotton World Statistics. Forecasts of B_t are available from OECD sources, and D_t can be obtained from an empirical version of (3).

The French model seeks to expand upon the AB model. One of French's contributions is to derive (3) from a more elaborate specification. He first postulates a demand for total per capita fibers consumption (including both cotton and synthetic fibers) which depends upon the real price of textile fibers and real per capita income. As a second stage, the demand for cotton fibers as a proportion of total fiber consumption depends on the relative prices of cotton and synthetic fibers. French also postulates a stock demand version of (6) which has been expanded to include the rate of change of prices, the variance of real cotton prices, and the level consumption and production.

Another of French's contributions is to disaggregate production, demand, and stock holding equations by region of the world. After estimating the model, he attempts to simulate world price behavior. Unfortunately, his simulations did not always converge. To rectify this problem, French chose to abandon his stock demand equation and instead include a Hwa-type equation. With this substitution, model simulations were determined to be successful.

IV. Alternative Approaches to Cotton Price Determination

This section reports on three alternative approaches to forecasting cotton prices. For each alternative price equations are estimated. These equations are used to forecast price for the 1981/82 crop year. The resulting forecasts are compared to actual 81/82 price levels. The United States farm price for $1\frac{1}{16}$" strict low middling (SLM) grade cotton fibers was chosen as a proxy for world cotton prices. In recent years world production of $1\frac{1}{32}$" - $1\frac{3}{32}$" cotton fibers comprised about 60% of the total volume of world production. The United States is the worlds's largest exporter of $1\frac{1}{16}$" cotton. American cotton markets are noted for their efficiency and USDA data collection methodologies are highly regarded for their reliability. For all these reasons the U.S. $1\frac{1}{16}$" SLM price seemed an appropriate choice for a representative world price

A. A Hwa-Type System of Equations

Various versions of (8) were estimated. The best estimates using ordinary least squares was:

$$P_t = \underset{(4.2)}{-211.92663} + \underset{(3.9)}{0.46923}P_{t-1} + \underset{(6.2)}{0.03593}D_t \underset{(2.3)}{-0.0054166}(S_{t-1}+Q_t) \underset{(3.8)}{+0.34307}POLY_t$$

$R^2 = .864$ SE = 6.86 DW = 2.329 Period 1961/62-1980/81

P = U.S. farm price of strict low middling $1\frac{1}{16}$" cotton. Average crop year price in U.S. cents per pound from U.S. Department of Agriculture's Agricultural Marketing Service.

C = Cotton fiber consumption (i.e., "disappearance") in noncommunist countries. Crop year data from the International Cotton Advisory Council's <u>Cotton World Statistics</u> in thousands of metric tons.

$S_{t-1}+Q_t$ = Cotton fiber "availability" (i.e., beginning stocks plus production) in noncommunist countries. Crop year data from the International Cotton Advisory Council's Cotton World Statistics in thousands of metric tons.

POLY = U.S. cents per pound for polyester fiber. Calendar year data from U.S. Department of Agriculture.

To forecast P for the 1981/82 crop year, data was required for 1980/81 ending stocks, 1981/82 production, 1981/82 consumption and 1981 calendar year polyester prices. To use the equation above to forecast 1981/82 crop year prices in, say, September, 1981, the following data sources would have been available. The July 1981 issue of Cotton World Statistics contained preliminary estimates of 1980/81 ending stocks. The July 1981 issue of Cotton: A Monthly Review of the World Situation, a publication of the International Cotton Advisory Council, contained a preliminary forecast for 1981/82 production. (Note that harvest of this crop begins in August 1981 in some countries). The U.S. Department of Agriculture had published at least 6 months of data for polyester prices. It was necessary to forecast polyester prices for the remaining months of the calendar year. This data series is remarkably stable in the short run, so trend forecasts could be expected to be reliable.

The most difficult to obtain input into the forecasting process is the demand for cotton fibers during the 1981/82 crop year. Since none of this data had been released by the presumed September 1981 forecasting data, a forecasting technique for demand is required. The approach chosen was to estimate an empirical version of (3).

Various specifications of (3) are possible. The most satisfactory results came from using "double log forms" (natural logarithms of both dependent and independent variables). Independent variables included world income (in constant dollars), real dollar polyester prices, and real dollar $1\frac{1}{16}$" SLM prices.

Observe that (3) postulates that demand depends on the current price level and (8) postulates that current price depends on demand. If these hypotheses are correct, (3) and (8) comprise a simultaneous equation system. To allow for the statistical implications of simultaneous equations, the demand equation was estimated using an instrumental variable technique, where the instruments were all predetermined variables in (3) and (8). The result of that instrumental variable approach was that the coefficient of the current price variable was statistically insignificant while the lagged price variable was highly significant. (It should be noted that Adams-Behrman and French report similar results). Given this result, it is appropriate to use ordinary least squares to estimate both the demand function and the Hwa-type price equation.

The most attractive demand function estimate was:

$$\ln D_t = \underset{(15.7)}{7.7364} - \underset{(2.6)}{0.07879}\ln RP_{t-1} + \underset{(3.5)}{0.30765}\ln Y_t + \underset{(1.1)}{0.03915}\ln RDPOLY$$

$R^2 = .874$ SE =.00219 DW = 1.95 Period 1961/62-1980/81

where

D = cotton consumption in noncommunist countries.

RP = U.S. average farm price for the crop year of strict low middling $1\frac{1}{16}$" cotton fibers deflated by the OECD gross domestic product deflator.

Y = Index of OECD real gross domestic product (1975=100). Calendar year data.

RPOLY = Dollar price of polyester fiber deflated by OECD gross domestic product deflator. Calendar year data.

Forecasts of demand for the 1981/82 crop year require the 1980/81 real

$1\frac{1}{16}$" cotton fiber price, 1981 calendar year real gross domestic product, and 1981 calendar year real polyester prices. The lagged $1\frac{1}{16}$" price was of course, available in September 1981. From the OECD's Economic Outlook one could obtain a 1981 claendar year OECD gross domestic product forecast which was compiled in July 1981. That source also contained price forecasts which could be used to deflate the 1981 polyester price series, (which would be based partly on published data and partly forecasted data).

Values used in forecasting were:

$POLY_{81} = 85$ $\qquad P_{80/81} = 82.99$

$RPOLY_{81} = 45$ $\qquad RP_{80/81} = 53.68$

$Y_{81} = 120$ $\qquad Q_{80/81} = 9453.3$

$S_{80/81} = 3295.7$

Using these values to solve for forecasted consumption and price result in a forecast for $D_{81/82}$ of 8471.7 thousand metric tons and for $P_{81/82}$ of 91.60 cents per pound. The actual average $1\frac{1}{16}$" price was 60.48 cents per pound. The forecast from a Hwa-type price equation over estimates actual price by 50%.

B. A Lagged Price Equation

A "limited information" approach to price determination is to assert that current price depends only on past price levels. This is a "limited information" approach in the sense that the analyst may know nothing about the structure of the model or, alternatively, may have no data available other than past prices.

The best empirical relationship discovered between current and past prices was:

$$P_t = \underset{(0.2)}{1.38135} + \underset{(2.3)}{0.55742}P_{t-1} + \underset{(1.9)}{0.49833}P_{t-z}$$

R^2 = .616 SE = 12.041 DW = 2.2233 Period 63/64-80/81

To forecast the 1981/82 price requires price data for the two preceding years. That data was:

$P_{80/81}$ - 82.99 $P_{79/80}$ = 71.48

The forecasted 1981/82 price using this method was 83.26 cents per pound. This forecast overstates the actual 1981/82 price by 37%.

C. The Futures Market

There exists another approach to price forecasting which has not been considered. This approach is to use the futures market as a price forecasting device. Since the New York Cotton Exchange's No. 2 futures contract is based on U.S. $1\frac{1}{16}$" SLM cotton, it is an easy matter to use the Cotton Exchange's futures price to forecast the U.S. $1\frac{1}{16}$" SLM price.

It is possible that cotton futures prices are a biased estimate of acutal prices, particularly when those futures prices are compared to farm level prices. For that reason, it is wise to run a regression which can adjust for systematic biases. The U.S. $1\frac{1}{16}$" farm price was the dependent variable in the regression and the futures price the independent variable. For the purpose of this analysis, the independent variable is the average price during the month of July for the December futures contract. The dependent variable is the average December farm price (not the average price for the crop year, as in earlier regressions) for U.S. $1\frac{1}{16}$" SLM cotton fiber.

The best regression was:

$$\ln PD_t = \underset{(0.4)}{0.20519} + \underset{(7.0)}{0.95520} \; FPD_t$$

R^2 = .785 SE = .21672 DW = 2.69 Period 67/68-80/81

PD = U.S. farm price of strict low middling $1\frac{1}{16}$" cotton. Average December price in U.S. cents per pound.

FPD = December futures price for New York Cotton Exchange No. 2 contract. Average price during month of July.

It is possible to determine the ability of the futures market to predict the December 1981 average price for U.S. $1\frac{1}{16}$" SLM cotton, using the equation above. During July 1981 the average price for the December futures contract was 77.65 cents per pound. Using the equation to adjust for bias, the predicted December price is 78.45 cents per pound. The actual average December price was 55.11 cents per pound. The July futures market overpredicted the average December price by 52%.

V. Conclusions

Each price forecasting model discussed in Part IV above overestimated 1981/82 crop year average prices by large amounts. Even the futures market failed to predict the large decline which occurred in 1981/82. While it should be recognized that one of the most demanding requirements of a forecasting model is that it predict well at turning points such as 1981/82 when cotton prices declined sharply from the level of the preceding year, one should nevertheless be highly skeptical about any forecasting procedure which is capable of making such a large forecasting error.

One of the implications of this forecasting exercise is that a pricing strategy which fixes a price for the entire crop year is likely to lead to serious problems if policy makers are forced to rely upon price forecasts which can be in error by large amounts. If the forecasts available to policy makers, are vulnerable to errors anywhere near the size of those reported above, a crop year price based on information so misleading may result in substantial overpricing of the Egyptian cotton crop.