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COBWEB PHENOMENON AND FLUCTUATIONS IN SUGARCANE ACREAGE IN NORTH BIHAR

DAYANATHA JHA AND C. C. MAJI

Division of Agricultural Economics
Indian Agricultural Research Institute, New Delhi

Variability in sugarcane production has created important problems for the sugar industry in the country in recent times. The instability in production is reflected in gluts on the sugar factory gates in some years and acute scarcity in others. Substantial increases in *gur* price during the 'sixties further aggravated the malady and problems of sugarcane diversion from sugar to *gur* and *khandsari* manufacture became rather acute. In general, both the problems, that of inherent instability in sugarcane production and of diversion, have been more seriously felt in the traditional sub-tropical sugarcane growing belt, affecting the States of U.P., Bihar and Punjab.

The first of these problems, namely, instability in sugarcane production, forms the focus of this paper. There is a belief that there is some sort of regularity in the fluctuations and it shows a somewhat cyclical pattern. In his analysis of the impact of price movements on acreage, Dharm Narain observed oscillatory movements of cyclical character in both acreage and relative price of sugarcane. "The durations of cycles are not uniform but the tendency for both area and price to trace cycles of approximately four to six years' duration persists throughout."[1]

The cobweb theorem provides a theoretical explanation for such cycles. Though Dharm Narain did not go into a detailed analysis explicitly, he had sufficient evidence to remark that the price-area relationship in sugarcane was closely analogous to the two-way causation noticed in the cobweb phenomenon. He argues that "price cycles are, in the main, supply cycles and area cycles are, in the main, price inspired. The phenomenon portrays in essentials the working of the cobweb theorem."[2]

Expounding the cobweb hypothesis, Ezekiel[3] had enunciated three conditions which must be fulfilled, namely (*a*) production is entirely determined by producers' response to price under conditions of pure competition, (*b*) at least one full period is required before production can be changed, and (*c*) the price is set by available supply. It is quite clear that while the first two may be considered feasible, the third is not. Government intervention has been, perhaps, most pronounced in sugarcane pricing than for any other agricultural commodity. The system of minimum sugarcane prices has been

1. Dharm Narain : Impact of Price Movements on Areas under Selected Crops in India 1900-39, Cambridge University Press, London, 1965, Chapter 7, p. 86.
2. Dharm Narain : *op. cit.*, p. 101.
3. Mordecai Ezekiel, "The Cobweb Theorem," *Quarterly Journal of Economics*, Vol. LII, No. 1, February, 1938, p. 272.

in vogue since the mid-'thirties and on the sugar side also prices have often been regulated. This would seem to violate the cobweb assumptions but Waugh[4] has demonstrated that in spite of price interferences, the oscillatory movements characterizing the cobweb may persist, though in a modified form.

The major conceptual criticism levelled against the cobweb theorem is that though Ezekiel implicitly assumes a reversible long run supply curve, the model has generally been applied in the analysis of short run supply. Using the concept of a family of different short-term supply curves Akerman[5] argued that the theorem does not provide an explanation for fluctuations involving growing disequilibrium. Nerlove[6] demonstrated, with the help of the adaptive expectations concept and also, alternatively, of the Marshallian distinction between the short and long runs, that with a dynamic specification of supply alone, or both supply and demand, the explanatory power of the cobweb theorem may be substantially enhanced to cover Akerman's objections. He also presented preliminary empirical results to show that conditions of growing disequilibrium are, in fact, revealed with the help of the cobweb theorem.

Again, it is argued that the periodicity of the cycles actually observed is not explained by the cobweb theorem which, in the simplest case, leads by definition to cycles of twice the production lag duration. This led some to reject the cobweb theorem in favour of an alternative harmonic motion model, which, in turn, has been subjected to criticisms.[7] This brief reference to the conceptual controversies surrounding the cobweb theorem is just meant to show that the theoretical and empirical basis of the theorem is still in a developing stage.

No rigorous empirical work has been done on the application of the cobweb theorem in India. In other countries, it has been used to explain cycles in livestock production mainly. This paper seeks to examine whether the theorem can be applied to explain fluctuations in sugarcane acreage in North Bihar, over the period 1934-35 to 1964-65. During this period, only a very small fraction of the total sugarcane production was used for *gur/khandsari* manufacture and bulk of the cane was supplied to the 29 sugar factories located in the region. Figure 1 shows the movement of sugarcane acreage and of relative sugarcane price[8] over the period under reference. The variables have not been adjusted for trend. The diagram illustrates that the peaks and troughs in area generally follow those in prices, though with milder intensity and the 'cup-like' formations suggest the incidence of cobweb cycles. It also appears that both area and prices follow a 3—5 years' cycle period.

4. Frederick V. Waugh, "Cobweb Models," *Journal of Farm Economics*, Vol. 46, No. 4, November, 1964.

5. Gustav Akerman, "The Cobweb Theorem : A Reconsideration," *Quarterly Journal of Economics*, Vol. LXXI, No. 1, February, 1957.

6. Marc Nerlove, "Adaptive Expectations and Cobweb Phenomenon," *Quarterly Journal of Economics*, Vol. LXXII, No. 2, May, 1958.

7. L. D. McClements, "Note on Harmonic Motion and the Cobweb Theorem," *Journal of Agricultural Economics*, Vol. XXI, No. 1, January, 1970.

8. Sugarcane price paid by factories deflated by wheat price.

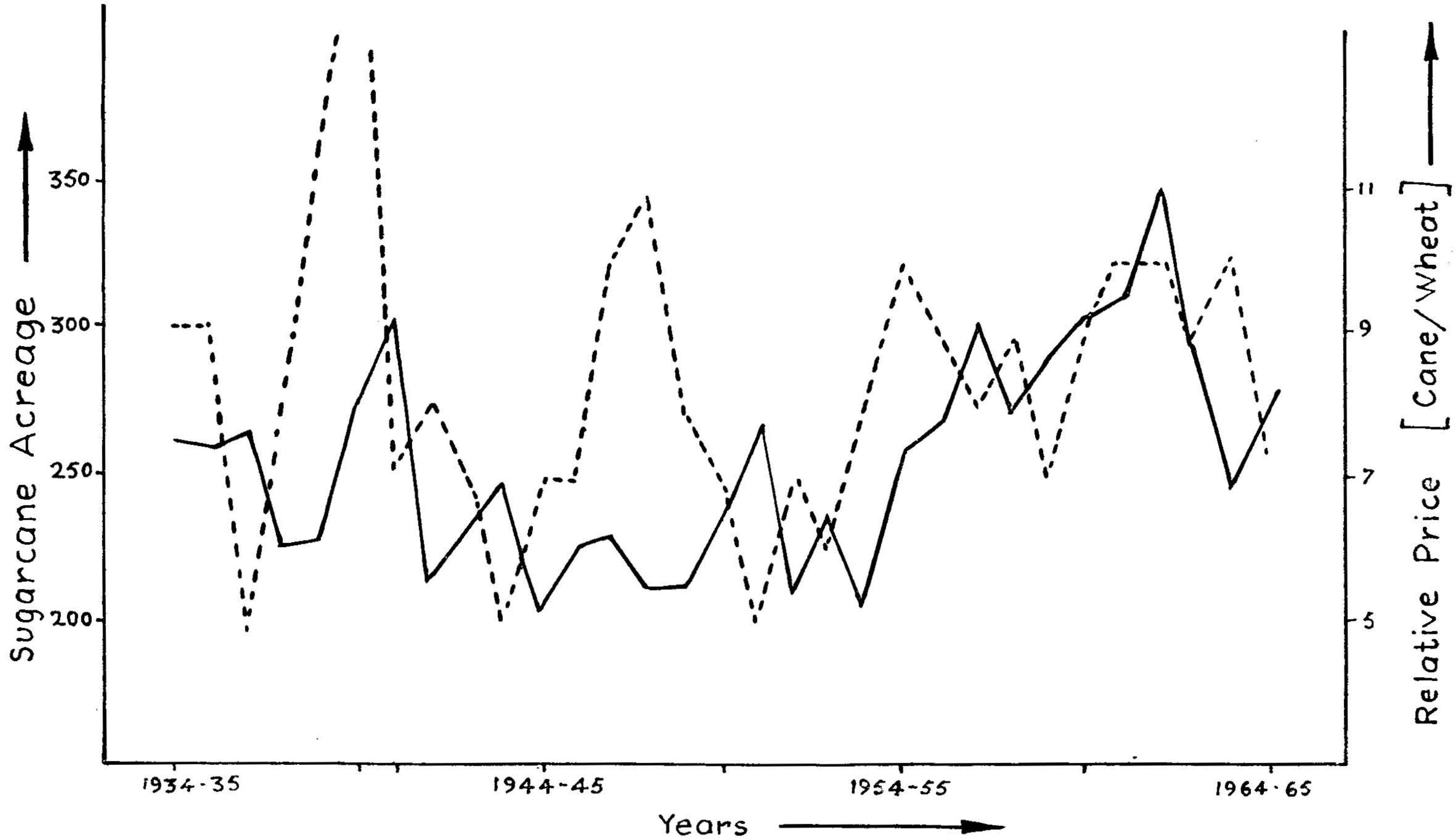

Figure 1—Movement of Sugarcane Acreage and Relative Prices

METHODOLOGY

The analysis is based on 31 years' time-series data from 1934-35 to 1964-65 (agricultural year). The relevant statistics on area, production, prices, rainfall, etc., were obtained from the Season and Crop Report published by the Government of Bihar. The main sugarcane belt in North Bihar comprises of four districts, namely, Darbhanga, Muzaffarpur, Saran and Champaran. Estimates for this region were prepared by aggregating the data for the above districts and using suitable weighting procedures.

Two specifications of the cobweb model have been used in this study. The first is the traditional version in which both supply and demand functions are defined in a partially static sense. In the second, the dynamic supply relation is used. This, according to Nerlove, represents an advancement both in theoretical basis of the model and also its applicability.

Two relations, one relating acreage to lagged price (supply response) and the other for demand of sugarcane acreage, have to be estimated. The variables considered in the supply and demand relations in this study were

Supply : $A^s_t = f\,(P^c_{t-1}\,,\, P^w_{t-1}\,,\, Y_{t-1}\,,\, R_t)$

Demand : $A^d_t = f\,(P^c_t\,,\, P^s_t\,,\, D^c_t)$

where A=acreage under sugarcane, P^c=price of sugarcane, P^w= price of wheat, Y=yield of sugarcane, R=pre-sowing rainfall, P^s=price of sugar and D^c=a dummy variable to denote periods of control on sugar price. The subscripts t and t—1 refer to time periods, d and s postcripts distinguish demand and supply relations. An additional dummy, D^a has also been specified to take care of the changes in the method of estimation of acreage from *chowkidari* to complete enumeration in 1949-50.

Model I. Traditional Cobweb Model

Let $A^d_t = a + b\,P^c_t$ .. (1)

$A^s_t = c + d\,P^c_{t-1}$ .. (2)

be the equations for demand for and supply of sugarcane acreage respectively, and

$A^d_t = A^s_t$ for all t .. (3)

the market clearing condition. Thus

$$P^c_t = \frac{c-a}{b} + \frac{d}{b} P^c_{t-1} \quad .. \quad (4)$$

is a first-order linear difference equation. Its solution shows that $\frac{d}{b}$ determines the nature of price movements. Since $b<0$ and $d>0$ generally, oscillations are indicated. If $\left|\frac{d}{b}\right| < -1$, the oscillations are explosive; $\left|\frac{d}{b}\right| = -1$ implies continuous oscillations and $-1 < \left|\frac{d}{b}\right| < 0$ leads to dampened oscillations.

Model II. Dynamic Supply Version[9]

Incorporation of adjustment lags in the supply relation yield the following reduced form for the supply function:

$$A^s_t = c\beta + d\beta \; P^c_{t-1} + (1-\beta) \; A^s_{t-1} \quad .. \quad (5)$$

where β is the coefficient of adjustment. From this, equation (1) and identity (3), we get another first-order difference equation

$$P^c_t = \frac{(c-a)}{b} \beta + \left[\left(\frac{d}{b} - 1\right) \beta + 1 \right] P^c_{t-1} \quad .. \quad (6)$$

The solution of this equation indicates that return to equilibrium will be achieved only if

$$\left| \left(\frac{d}{b} - 1\right) \beta + 1 \right| < 1$$

$$\text{or} \quad 1 - \frac{2}{\beta} < \frac{d}{b} < 1$$

RESULTS

Equations for demand for sugarcane acreage and acreage response were obtained separately. Only the finally selected equations containing significant variables have been presented here.

Model I

The linear equations obtained were:[10]

Acreage Response Function

$$A^s_t = \underset{}{219.1771} + \underset{(0.7348)}{0.9937^{*}\, P_{t-1}} - \underset{(0.5639)}{1.8539^{****}\, P^w_{t-1}} + \underset{(1.9876)}{4.2818^{***}\, Y_{t-1}} + \underset{(17.1967)}{62.5067^{****}\, D^a_t}$$

$R = 0.7673$

$d = 1.8068$

Demand for Sugarcane Acreage

$$A^d_t = 241.6368 - \underset{(0.9584)}{3.1865^{****}\, P^c_t} + \underset{(0.5793)}{1.5437^{***}\, P^s_t} + \underset{(21.2859)}{18.4390\, D^a_t}$$

$R = 0.6475$

$d = 1.5492$

9. For details, see Marc Nerlove, *op. cit.*

10. Figures in parentheses are standard errors. Levels of significance : * 20 per cent, ** 10 per cent, *** 5 per cent, **** 1 per cent.

The two equations clearly illustrate the influence of prices on both supply and demand sides and satisfy the hypothesized behaviour of the variables. The Durbin-Watson statistic shows that the null hypotheses for independence of error term cannot be rejected at 1 per cent probability level for either equation.[11]

As has been mentioned, the ratio of the coefficients for price in the supply and demand equations provides an idea regarding the nature of oscillation. Thus

$$\frac{d}{b} = -0.3087$$

implies a cobweb of the convergent type.

Model II

In this model, the acreage response function is based on Nerlove's adjustment lag formulation which, in the context of the cobweb theorem, is supposed to represent a better specification.[12] The demand equation remains as in Model I.

Acreage Response Function

$$A^s_t = \underset{}{193.2087} + \underset{(0.7442)}{1.3085^{**}}\ P^c_{t-1} - \underset{(0.5651)}{1.9879^{****}}\ P^w_{t-1} + \underset{(0.1502)}{0.2694^{**}}\ A^s_{t-1} + \underset{(19.4634)}{55.5826^{****}}\ D^a$$

$$R = 0.7542$$
$$d = 1.9418$$

Demand for Sugarcane Acreage

same as Model I, that is,

$$A^d_t = 241.6368 - 3.1865\ P^c_t + 1.5437\ P^s_t + 18.4390\ D^a_t.$$

The revised specification of the supply equation leads to an improvement in the magnitude and level of significance of the coefficient for sugarcane price, though the lagged yield variable was rendered non-significant. The value of the coefficient of adjustment (β) comes to 0.7306. In this case

$$1 - \frac{2}{\beta} = -1.7813$$

and $$\frac{d}{b} = -0.4107$$

11. On the basis of an approximation suggested by H. Theil and A. L. Nagar, "Testing the Independence of Regression Disturbances," *Journal of American Statistical Association,* Vol. 56, December, 1961.

12. L. D. McClements, "The Specification of Pig Supply Models" *Farm Economist,* Vol. XI, No. 10, 1969.

Thus the condition: $1-\frac{2}{\beta} < \frac{d}{b} < 1$: for convergence is satisfied in this case also.

Thus, both the models show that firstly, there is evidence for cobweb and secondly, it is of a convergent type. It must be mentioned that both the estimated equations contain a number of variables other than own price. This makes the determination of the precise time path rather complicated, even though it could be shown that so long as $\left|\frac{d}{b}\right|$ satisfies the condition for convergence of price to the equilibrium level, the series generated for other variables is also of a convergent type. The traditional model suggests a two-year periodicity of the price cycle which is not in conformity with observed behaviour. The second model implies a period of 2.3 years for nearly full adjustment. This gives cycles of 4—5 years' duration, assuming a static demand. This is much closer to the observed duration of the cycles. This supports McClements argument[13] that incorporation of the adjustment hypotheses in the supply relation improves the applicability of the cobweb theorem.

However, the inability to incorporate the influence of price intervention on both demand and supply sides, restricts the validity of general conclusions. It can only be said that the nature of supply and demand relations suggest a generally stable equilibrium.

PRICE ELASTICITIES—METHODOLOGICAL ISSUES WITH REFERENCE TO PERENNIAL CROPS

V. Rajagopalan, A. Sennimalai,
S. A. Radhakrishnan and A. Kandaswamy

Department of Agricultural Economics
Tamil Nadu Agricultural University
Coimbatore-3

Output decisions are generally claimed to have been influenced by prices and when products are at the end of their production process factor price is assumed to be given and product price becomes the relevant variable. As regards perennial crop with heavy initial investment plus varying annual costs, current product price seems to influence current output marginally and prices of previous periods would have greater relevance for current production. Related to this assumption is the expectation calculus of price for a given period and decision.

13. L. D. McClements, *op. cit.*