"Cobwebs," to appear in *Famous Diagrams in Economics*, eds. Mark Blaug and Peter Lloyd. Edward Elgar Publishing.

History and Background

Mordecai Ezekiel's 1938 paper made "The Cobweb Theorem" and his famous diagram well-known to every student of economics. Ezekiel was attempting to explain apparent self-perpetuating fluctuations in the prices of some agricultural commodities observed by Hanau (1927), Schultz (1930), and Coase and Fowler (1935). Tinbergen (1930), Ricci (1930), Leontief (1934), and Kaldor (1934) drew similar diagrams. Kaldor gave the name "Cobweb Theorem" to the phenomenon.

Kaldor (1934, p. 132) writes "...once allowance is made for the fact that in the real world functional adjustments take time and different forces in the system may operate with different 'velocities of adjustment' it may become possible to construct cases--*under the assumption that ruling prices are always expected to remain in operation*...where the successive reactions lead away from, rather than approach, an equilibrium position." As Kaldor points out the most important assumptions underlying cobweb phenomena are lags in responses and so-called "static expectations."[1]

Hanau's aim (1927) was to forecast the price of hogs at the Berlin market. The period of gestation for a piglet is 114 days, or approximately 3.75 months; the period from birth (farrow) until the hog is ready to be marketed (finished) is approximately six months in the U. S., but it was considerably longer in the Germany of Hanau's time, on the order of twelve months."[2] Allowing for some time to breed a sow, and after some experimentation, Hanau settled on a relation between the supply of hogs for slaughter and the ratio of the price paid and an index of feed prices eighteen months previously. Since the current price revealed a negative correlation with the number of hogs brought to market in Berlin, Hanau concluded that hog prices followed a cyclical path. Ezekiel knew Hanau's work well, having reviewed his monograph in the *Journal of the American Statistical Association* (1928).

Schultz (1930) was interested in interpreting the statistical relation between the price of an agricultural commodity and its quantity marketed in terms of demand functions. His work and that of Henry Moore (1925, 1929) met with a great deal of criticism.[3] The basic question was how to interpret observations on market prices and quantities in terms of supply and demand equilibria. Tinbergen (1930) suggested a

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[1] Arrow and Nerlove (1958, p. 297). As they point out, however, this is far from a realistic assumption in any real-world context.
[2] USDA/ERS, http://www.ers.usda.gov/Briefing/hogs/background.htm (accessed 10/15/2008).
[3] See E. J. Working (1927) and Ricci (1930)

solution to the problem in terms of discontinuous supply adjustment, instantaneous demand adjustment and static expectations. Ezekiel (1938) tried to synthesize all this into a general theory of cobweb phenomena.

Ezekiel's Diagram

Ezekiel's famous diagram (1938, pp. 262 and 264) is reproduced here in a single figure, which has four panels: the basic setup; case 1, permanent oscillation; case 2, explosive oscillation; case 3, convergent oscillation. There are several points to note about this sequence of diagrams: The supply and demand curves, labeled, respectively, $S_TS'_T$ and D'_TD_T are so-called "total" demand and supply curves. These "...relate the total supplies on the market in a succession of periods to prices prevailing in each of those periods, and determine a curve describing that relationship.... If the total supply of the commodity cannot be changed within each period with which they are dealing in response to the prices of that period." (Ezekiel, 1938, p.259) Note, in this case, demand includes reservation demand for an amount to be held in storage until next period and the total supply this period includes any carry-over from last period. If the commodity is perishable and cannot be stored, these quantities are zero. Let the quantity supplied in the first period be Q_1. Price the first period, P_1, must be such as to clear the market in the first period. If producers have static expectations, i.e. expect the price in the first period will hold forever, and can adjust in the next period , then supply which includes carry –over from the first period will be Q_2 and the price, P_2, must clear the market, including reservation demand, in the second period, and so on *ad infinitum.* The panel labeled "Cobweb Case 1" depicts a total supply curve which is the mirror of the demand curve; in this case , no matter what the starting point, the prices and quantities will oscillate endlessly about the equilibrium intersection of the two curves, unless of course the starting point is exactly there. The third panel labeled "Cobweb Case 2" depicts a total supply curve which is everywhere of greater slope everywhere than the total demand curve; in this case, if the starting point is anywhere other than the equilibrium, prices and quantities over time will diverge from the equilibrium. The fourth panel labeled Case 3 depicts a supply curve which is every where of lesser slope than the demand curve; in this case, from any point prices and quantities will converge to the equilibrium. Within any period the quantity is fixed and the price determined by demand; the supply curve, however, reflects producers' plans this period, only to be realized in the subsequent period. Ezekiel tries to suggest this by drawing the curves not as "...intersecting, but rather lapping over one another without real contact." (Ezekiel 1938, p. 263)

Ezekiel himself discusses a number of limitations and difficulties with the cobweb theory applied to agricultural commodities. Production must be determined completely by producers' response to price under conditions in which individual producers expect their individual actions will have no effect on the price they will obtain in the market and on the assumption that the current price will hold when their production comes to market (static expectations). Prices must be set by the supply available and the time needed for changes in production requires at least one full period and is not a partial response occurring over several periods of time. These assumptions are obviously unrealistic for most agricultural commodities. Moreover,

in the case of crops, weather may greatly alter actual production from that which is planned. Of course, in general, both supply and demand may be affected by stochastic shocks.

Criticism and Extensions

The cobweb theorem was subject to considerable criticism following Ezekiel (1938). Buchanan (1939) examined more closely the implications of the underlying assumptions for the supply response of producers of a disturbance in equilibrium. He questioned the assumption that "...while output changes according to the assumption that producers always expect the price ruling in the last period to prevail in the next, the supply curve remains unaltered. In other words, the supply curve is completely reversible throughout its whole length with respect to each period." (p. 68) Supply response is assumed to occur fully over one period; there is no partial adjustment and no difference between long run and short run supply response. With no entry and exit producers always lose more net revenues in a period of low prices than they gain in a period of high prices. Eventually they must cease production altogether. Free entry only complicates matters. But the implication is that perpetual or divergent fluctuation cannot persist. Buchanan's careful examination of previous writers on the cobweb suggests a diversity of views on just what kind of supply response is consistent with the theorem. (pp. 77-78) He also questions the assumption of no partial adjustment either over many periods or within one period. (p 79) Finally he says, "...the inviolable assumption that people never learn from experience, no matter how protracted, is at least debatable." (p. 81) To say the least!

Åkerman (1957) introduced a difference between long and short run supply functions: "If a farmer has experienced an appreciable price change for one of his products ... and, therefore, wants to extend its cultivation during the following year, he will meet with greater immediate difficulties than if the extension could be brought about gradually over a period of years. ... All [earlier authors assume] ...one unique normal supply schedule without distinguishing between short- and long-term schedules. This is the main reason why they have ascribed quite exaggerated properties to the cobweb phenomena." (p. 154-155) Åkerman regards the possibility of a growing disequilibrium rather improbable. (p.158)

Until Nerlove (1958a) almost studies of agricultural supply response were based on the two questionable assumptions underlying Ezekiel's (1938) presentation of the Cobweb Theorem: static expectations and full adjustment to price changes within one period.[4] Nerlove (1958a, 1958b) introduced *adaptive expectations* and *partial adjustment* models of farmers' response to price in a cobweb model.[5] Nerlove found that the ratio of the slope of the demand curve to the slope of the supply curve would have to be larger in absolute value as the adaptive expectations model approached the traditional static expectations. Partial adjustment has the same effect. Thus, while the scope of stability of equilibrium is enhanced by adaptive expectations

[4] See Nerlove (1958a, pp, 66-82) for a review of these studies.
[5] Various models of expectation formation, *extrapolative, adaptive, implicit, futures-based,* and *rational* are discussed by Nerlove and Bessler (2001, pp. 166-177) and related to models of partial adjustment.

or partial adjustment or the two in combination, the possibility of theoretical instability and continuing losses by producers is by no means eliminated. Nerlove's study of agricultural supply response (1958a) was successful in demonstrating the farmers were indeed responsive to prices, it accounted for the great surpluses that were built up in the post-war years, and was indirectly but nonetheless deeply influenced by Ezekiel's famous diagram.

In his paper, "Rational Expectations and the Theory of Price Movements," Muth (1961) advances the theory that expectations "... are essentially the same as the predictions of the relevant economic theory. In particular, the hypothesis asserts that the economy generally does not waste information, and that expectations depend specifically on the structure of the entire system." Under this hypothesis he describes producer behaviour for a simple model of supply and demand with fixed production lag, that is the model on which Ezekiel based his cobweb theorem. He finds that with positively serially correlated shocks to the supply function, rational price expectations are a weighted average of past prices in which the weights depend upon the parameters of both the demand and supply functions. When shocks persist forever (i.e., a unit root in supply shocks), the model reduces to adaptive price expectations of the sort used by Nerlove (1958a), only the coefficient of expectations is now a simple function of both the slopes of the supply and demand functions.[6]

Conclusion

The cobweb theorem is fatally flawed as a theory of agricultural price movements, it has little empirical relevance, nor is it supported by any empirical evidence. Ezekiel's famous diagram has nonetheless had a profound and lasting influence in the development of dynamic models of agricultural supply and other dynamic economic models and of the rational expectations hypothesis.

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[6] Nerlove and Fornari (1998) have applied an econometrically feasible variant of rational expectations to explain stocks and prices in the U. S. cattle industry and find it works quite well.

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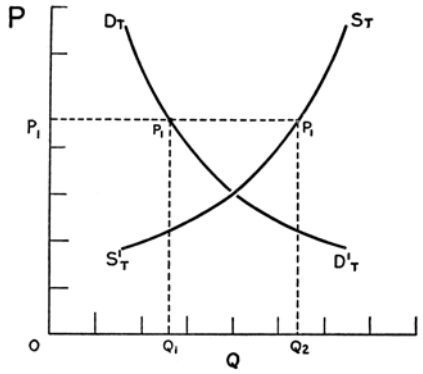
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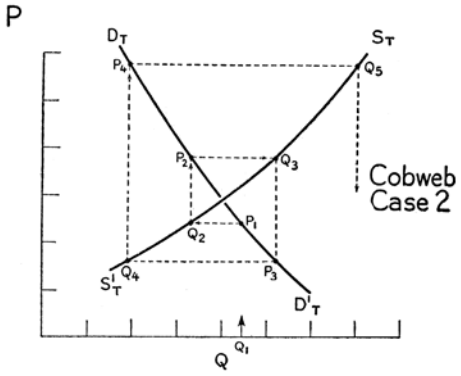
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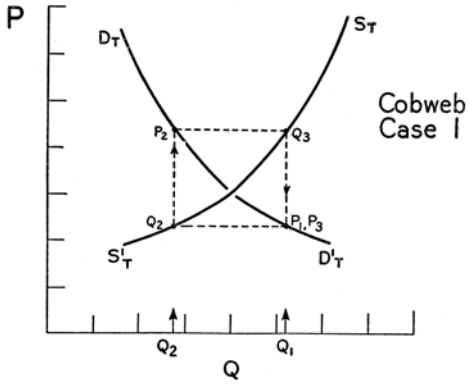
Case 2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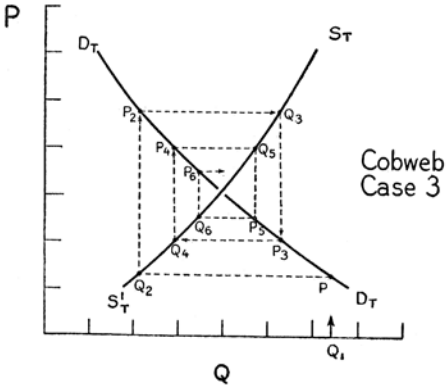
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