On the Existence of Stable Equilibria in Agriculture

Stephan J. Goetz[*]

Abstract

Problems of instability and disequilibrium in U.S. agriculture are synthesized within a single conceptual framework. Agricultural and non-agricultural sector offer curves are used to illustrate why it may not be feasible to achieve and maintain equilibrium *and* price stability in U.S. agriculture. Empirical evidence on resource disequilibrium and instability in the ratio of prices paid and received by farmers is presented.

Key words: instability, disequilibrium, offer curves, U.S. agriculture, policy

Two persistent quandaries of U.S. agriculture, output price instability and supply and demand disequilibrium have, for the most part, been analyzed independently and separately in the literature. Galbraith and Black conducted one of the earliest studies of supply and demand imbalances. They attempted to explain the paradox that agricultural production was maintained during the depression of the 1930s while the output of seven other sectors declined. Later Schultz, D.G. Johnson (1950), Cochrane, G.L. Johnson and Hathaway (1974) further analyzed the causes of disequilibrium. The inability of resources to move freely in and out of agriculture, implying an inelastic short-run supply curve, was central to explaining persistent disequilibrium, together with relatively stable but secularly declining demand growth rates.

A parallel literature evolved to address problems of price and earnings instability in agriculture (e.g., Firch; 1965, 1977). The earliest work included Schultz and D.G. Johnson (1947). Cochrane (p. 4) later wrote that the myth held by many "reasonable and modern" individuals was that...

... (1) there is some stable optimum level and pattern of prices, incomes and production for agriculture; (2) this optimum pattern is knowable ...; and (3) with some "straight" thinking and action agriculture could and would move to this optimum level and pattern ... *and then stay there.*

In his seminal paper, Schuh argued for a greater macroeconomic orientation of agricultural economists, which could be achieved by incorporating sectoral linkages of agriculture with both the U.S. and world economies in policy analyses. Related work included D.G. Johnson (1975, 1980), Hathaway (1981), Gardner (1981) and Tweeten (1983).

The dichotomous analytical approach to instability and disequilibrium is illustrated in Tweeten's (1989) book, *Farm Policy Analysis.* Low returns and instability are discussed in separate chapters (4 and 5, respectively).[1] Recent

applications of partial and general computable equilibrium and other simulation models may appear, on the surface, to hold promise in analyzing the problems interdependently. However, while providing important results, the explicit focus of most simulation studies is either on instability *or* on depressed returns, but not both.

For example, Glauber et al. compare four different approaches to stabilizing commodity markets. Hertel examines the implications of reducing agricultural producer subsidies, given the mobility of technology and inputs, under the assumption of partial equilibrium. Neither of these models provides a conceptually explicit link between resource disequilibrium and price instability. By definition, they also assume an optimal equilibrium can be attained, at least in the short run. Gardner (1992, p. 67) concludes that "... the basic farm model problem successfully integrated observations, theory, and econometric work to establish inelasticity of commodity supply and demand as a plausible cause of commodity price instability, but only by loose inference as the cause of low farm incomes." More recently, Chavas and Holt use chaos theory to study instability in dairy markets. They conclude (p. 120) that "... a steady-state equilibrium does not exist in the U.S. dairy market under an inelastic demand."

This paper combines the instability and disequilibrium problems into a single model, and shows how the two concepts can reinforce one another. Offer curves (*OC*) based on inelastic demand in the agricultural and non-agricultural sectors are derived together with a government intervention function, to illustrate why it may not be feasible to achieve and maintain resource equilibrium *and* price stability in agriculture, as suggested by Cochrane in the above quote. The model uses general equilibrium theory, but relies on graphic rather than numeric analysis to show how instability may co-exist with a tendency toward depressed returns.

The Offer Curve Framework

Offer (reciprocal demand) curves trace in product space the amount a country, region or sector is willing to forego of the good(s) produced locally in exchange for the good(s) produced by a trading partner. In contrast to partial equilibrium models of trade, which are based on three-panel sets of Marshallian supply, demand and excess supply and demand curves for a single commodity, *OC*s summarize trade in all commodities of two economies or sectors, thus permitting a general equilibrium analysis of change in the entire sector as relative prices change. Under assumptions of competitive behavior, offer curves for the agricultural (*a*) and non-agricultural (*n*) sectors are obtained by maximizing utility U^i in each sector (*i=a,n*) subject to a production or endowment (reflecting resources of the previous period) and trading constraint:[2]

$$\max_{\{A,N\}} U^i = U(I_c) + \lambda^i(\Sigma pI_t - \Sigma pI_e) \qquad (1)$$

where *I=A,N* denotes quantities of the agricultural and non-agricultural commodity bundle, *c* denotes consumption, *t* is trade, *e* indicates endowments produced with the flow resources labor (*L*) and capital (*K*), λ^i is an undetermined Lagrangean multiplier, and $p = p_a/p_n$ is the ratio of agricultural to non-agricultural product prices.[3] The commodity space is limited to $\mathbf{R}^2_{(+)}$ to allow a geometric exposition; the extension to $\mathbf{R}^n_{(+)}$ is relatively straightforward. The underlying production functions in each sector are assumed to be of the form $I_e^i = f^i(L^i, K^i)$, so that A_e^i and N_e^i depend on technology and resources allocated to sector *i* at a given point in time.[4] Short-run offer curves for each sector *i*, $A_t^i = \xi^i(A_e^i, N_t^i, N_e^i)$, are therefore a function of tastes (utility), resource endowments and technology in the sector. An illustrative offer curve is derived in Appendix 1. In the long run, when one or more of these factors is variable, the curves may shift and exhibit different elasticities. The only movement possible in the short run, once agricultural production has been determined, is *along* the curves, reflecting alternative relative prices and quantities traded with the non-agricultural sector.

Output from the agricultural sector increases over time as the results of output-increasing research are adopted by farmers, thereby shifting the *OC*. Similarly, over time this curve reflects the cumulative effects on producers of incentives provided by the government – including exchange rate adjustments, interest rate policies and

commodity storage programs – designed to achieve goals such as food self-sufficiency or land conservation.

Two important elasticities characterizing an *OC* are the elasticity of the offer curve,

$$\eta = (dN_t/dA_t)/(N_t/A_t),\qquad(2)$$

and the elasticity of demand for imports,

$$\mu = (dN_t/N_t)/[d(A_t/N_t)/(A_t/N_t)].\qquad(3)$$

The elasticity of the offer curve equals the ratio of the marginal to the average terms of trade, or the percent change in imports divided by the percent change in exports; it is analogous to a production elasticity. The elasticity of import demand is the percent change in imports resulting from a percent change in the relative price of the imported good. Since $\eta = \mu/(\mu+1)$, $\eta<0$ if $\mu\in(-1,0)$ (see, e.g., Chacholiades, p. 174). Thus, if the demand for imports is inelastic, the offer curve is backward-bending.

Empirical analyses of the demand for food consistently reveal an inelastic demand (see, e.g., Tomek and Robinson; the classic article by George and King; Metzler; and Gardner (1992)). Recent empirical evidence on demand elasticities for major agricultural "import" categories, such as material, hired labor and machinery and energy for 10 regions of the U.S. suggests that farm-level input demand is also inelastic; 28 out of 30 region-input combinations showed inelastic demand: $-1<\mu<0$ (Shumway and Alexander). Based on these considerations, the offer curves in Figure 1 are drawn as backward-bending curves with intersections occurring in the inelastic ranges at points E^0, E^1 and E^2, which represent equilibrium barter exchange ratios. Here quantities offered equal quantities demanded in both sectors. Associated with each point is a ray from the origin (w, v and y) measuring relative prices of agricultural and non-agricultural products.

Disequilibrium, Instability and Government Intervention

Next the stability of each equilibrium point is examined. Assume the economy is initially at E^2

Figure 1. Offer Curve Analysis of Disequilibrium and Instability in U.S. Agriculture
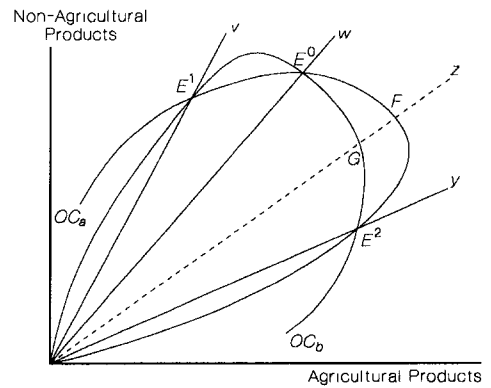
with relative prices given by y. If a temporary disturbance increases the relative price of agricultural products to z, the economy moves to points F on OC_a and G on OC_n. Dropping perpendicular lines from G and F to both axes in the diagram, it is clear there is an excess supply of agricultural products and excess demand for non-agricultural products. For markets to clear, relative prices of agricultural products must fall and the economy returns to E^2, which is therefore a stable equilibrium: if a disturbance (such as a drought) moves the economy away from E^2, the forces of supply and demand will return it to that point. Using the same reasoning, E^1 is also a stable equilibrium.

Now assume the economy is at E^0 with parity between agricultural and non-agricultural product prices, shown as $w \equiv p_o = 1.0$. At price ratio p_o, the value of agricultural commodities exported from agriculture equals the value of non-agricultural products exported from the non-agricultural sector (note: $N_x^n=N_x^a$, where x denotes exports and m imports):

$$p_o A_x^a (p_o) = N_x^n(1/p_o)\qquad(4)$$

With an inherent tendency towards over-production following G.L. Johnson's theory of asset fixity (see, e.g., Johnson and Quance) and Cochrane's agricultural treadmill, an excess supply of agricultural products causes relative prices to fall towards E^2.

Imbalances in quantities traded between the two sectors are characterized with the following differential equation of price instability with output disequilibrium:

$$dp/p \; = \; \dot{p} \; = \; A_x^a \, (p) - A_m^n \, (1/p) \qquad (5)$$

Equation (5) relates price variability to resource disequilibrium in agriculture; it illustrates how the market reacts to correct for disequilibrium which, because of the instability brought about by the configuration of the offer curves, reinforces the tendency toward deteriorating terms of trade once relative prices decline towards z in Figure 1. When markets clear and prices are in equilibrium ($p = p_o$), there is no pressure on prices to change ($\dot{p} = 0$). This may occur at any of points E^0, E^1 and E^2 in Figure 1. Therefore, Figure 1 captures inherent instability in relative prices along with conditions of resource disequilibrium anywhere along the arcs between the equilibrium points. There are, however, other circumstances under which prices may be "locked in" and remain stable. To complete the model, introduce a government intervention function,

$$\gamma^* \; = \; \left\{ \begin{array}{ll} \theta(\varepsilon, p^*) \; \text{if} \; p^*-p>\varepsilon \\[2em] 0 \quad \text{otherwise} \end{array} \right. \qquad (6)$$

which is triggered when relative prices (p) fall below some politically unacceptable threshold (ε). Short-term policy instruments available to support relative prices include direct price supports and subsidies and the creation of government inventories along with export enhancement programs. Long-term intervention strategies include production controls such as quotas and acreage set-aside programs. When γ^* is in effect, $\dot{p}$ is 0 for the duration of the intervention, and

$$0 \; = \; -\theta(\varepsilon, p) \; + \; A_x^a \, (p) \; - \; A_m^n \, (1/p) \qquad (7)$$

In Figure 1, government intervention permits markets to clear by removing the equivalent of quantity $\theta(\varepsilon,p)$, measured as the distance between G and F, of A from the market so as to freeze relative prices at z. Now, with the economy locked into a position given by relative prices z through public intervention, there is overproduction (resource disequilibrium) in agriculture. The

relative price of agricultural goods would need to increase to restore equilibrium at E^0.

It is conceivable that points E^1 and E^2 do not exist--i.e., the curves are shaped so that they intersect only once, at E^0. Alternatively, there may be multiple intersection points yielding successive stable and instable points of equilibrium (Figure 2a), or worse yet, a range of overlap may exist between the curves so there is no unique point of intersection (Figure 2b). Perhaps it is in the latter sense that Cochrane argued there is no stable equilibrium level of prices, incomes and production in agriculture, as indicated in the above quote. This offer curve analysis thus permits simultaneous consideration of instability, resource disequilibrium and public intervention in agriculture in a general equilibrium context. Applications are discussed in the following section.

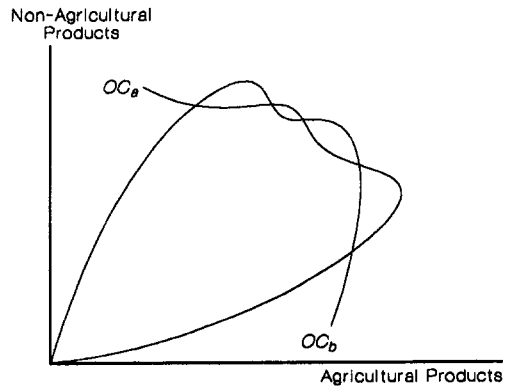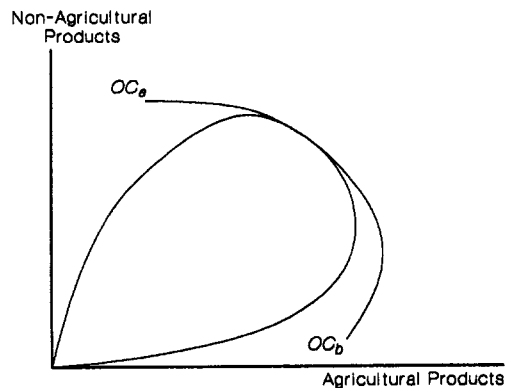Figure 2a. Backward-Bending Offer Curves with Multiple Intersections

Figure 2b. Backward-Bending Offer Curves with an Overlapping Range

Applications

Indices of prices paid and received by farmers are used as measures of relative prices facing the agricultural sector in Figure 1. In addition, farmers purchase non-agricultural goods such as clothing and automobiles, which are ignored for the present purposes.[5] The ratio of prices paid to prices received by farmers declined starting in the mid-1940s (Figure 3), implying pressure on relative prices to move from a point such as E^0 to E^2 in Figure 1. An exception is the "commodity boom" period in the early 1970s, during which prices received increased sharply relative to prices paid (implying a movement towards E^1).

The focus here is on product terms of trade. Factor or input terms of trade are another important set of relative prices, which are equal to the output/input ratio of a sector under assumptions of perfect competition and constant returns to scale. Factor terms of trade have increased by 61 percent in favor of agriculture between 1910-14 and 1986 (Tweeten, 1989, p. 3). As Tweeten points out (*ibid.*), product terms of trade are "... much inferior as a measure of farm economic health to ..." factor terms of trade. Nevertheless, because much of public policy intervention focuses on (deteriorating) relative product prices, and because offer curves for the products display resource disequilibrium, product terms of trade are used here in the context of Figure 1 in place of factor terms of trade.

Variability or instability in the price index series is defined as a year-to-year percent change.[6] Instability in the ratio of prices was especially large in the early 1970s and more or less confined to a band of approximately 10 percent the remainder of the time (Figure 4). Resource use in agriculture, as measured by excess capacity in land (i.e., as a percent of harvested area), was close to equilibrium in the 1940s and 1970s, and appears to be heading in that direction again in the early 1990s (Figure 5). A comparison of Figures 4 and 5 suggests periods of resource equilibrium are associated with greater relative price *instability*, and conversely. This is consistent with a movement of the economy towards a point such as E^0: resource equilibrium is brought about at the expense of price instability.

Figure 3. Index of Prices Paid and Received in U.S. Agriculture, 1939-90
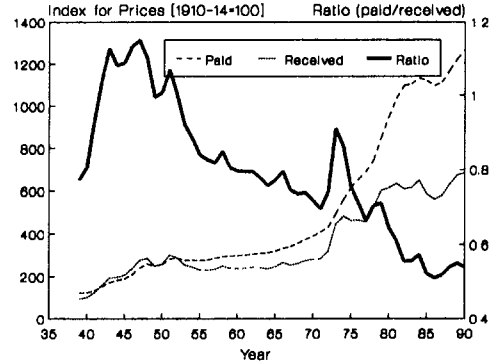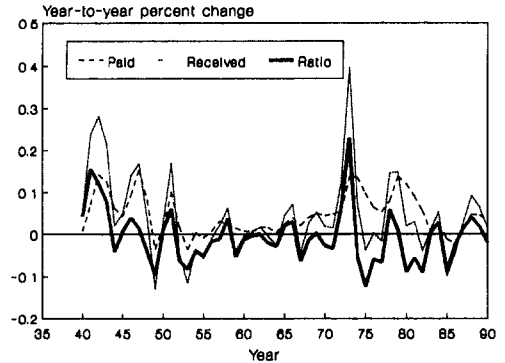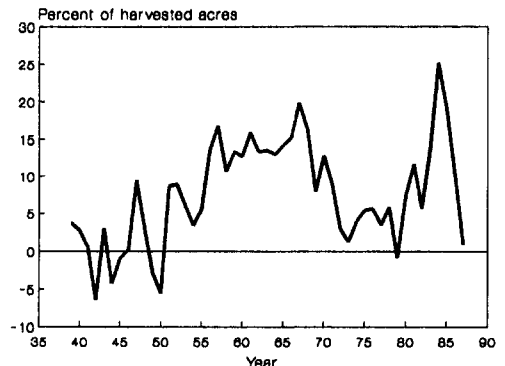Source: USDA Agricultural Statistics.

Figure 4. Year-to-Year Change in Prices Paid and Received in U.S. Agriculture, 1939-90

Source: Calculated from data in Figure 3.

Figure 5. Resource Disequilibrium of U.S. Agriculture: Excess Capacity of Land, 1939-88

Source: Dvoskin (data for 1987-88 are estimated).

Price level z in Figure 1 generally mirrors conditions prevailing in U.S. agriculture during the 1950s and 60s, with excess capacity $(G-F)$ in agriculture, and a relatively stable but declining price ratio. In Figure 1 resource equilibrium corresponds to a movement from G and F towards E^0 and $w = 1$ in the early 1970s, which is also reflected in Figure 3 by the peak in the ratio of prices received to prices paid by producers. Close scrutiny of Figures 3 and 5 also reveals an inverse relationship between excess production capacity in agriculture and relative prices facing producers over certain time spans, such as 1950 and 1970 and again between 1980 and 1985, when excess capacity was increasing as relative prices were falling. However, this relationship is not stable over time: excess capacity fell from 1971 to 1974 while relative prices reached a peak in 1973.

The case of rising interest rates, as experienced in the early 1980s, can also be analyzed in terms of Figure 1. Since the capital-labor ratio in agriculture is twice that of the rest of the economy (e.g., Thompson, p. 592), input prices facing agriculture would increase relative to agricultural product prices, driving relative prices towards z in the short-run (assuming the cost of capital to agriculture is not subsidized). Conversely, declining interest rates experienced during the early 1990s imply an improvement in the terms of trade for agriculture. This is manifest in a movement to point E^1 and a price ratio such as v. This condition, along with insufficient capacity, existed in the 1940s and early 1950s, and again in 1973 and 1980.

A key question for policy purposes is where the line of price parity lies relative to the three intersections of the offer curves. Figure 3 illustrates that parity was attained in the years 1942, 1949 and 1952. Points E^0, E^1 and E^2 are efficient in the sense that quantities demanded equal quantities supplied. At most only one point can correspond to a price ratio of parity, however, and distributional consequences vary depending on the particular price ratio. If the ratio of parity happens to lie at z (= 1) in the short-term, a dilemma arises, since the objectives of maintaining a supply and demand balance and parity cannot be achieved simultaneously. The government can support prices, but this begs the question, "at what level"? Figure 6 illustrates the extent of public intervention in

Figure 6. Producer Subsidy Equivalents, Government Outlays per Farm and Index of Prices Received to Prices Paid, 1955-89
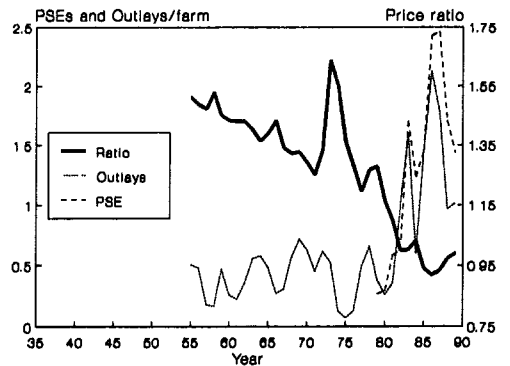
Source: OECD for PSEs, Gardner (1992) for outlays, Figure 3 for ratio.

agriculture using two different measures which closely track each other. While the relationship between these two series and the relative price ratio facing farmers is not obvious, decreases in the price ratio have recently been associated with increases in support levels, while the increase in the ratio in 1987 was accompanied by reduced support.

Summary and Conclusion

Offer curves combined with a government intervention function can be used to analytically synthesize the problems of resource disequilibrium and instability in agriculture. Offer curves depend on tastes, technologies and resource endowments. The interaction of these factors in the case of U.S. agriculture leads to persistent price instability and resource disequilibrium, compounding problems of variability in agricultural production caused by uncertain weather. The conclusion reached here is thus similar to Cochrane's: first, there is no singular stable *and* optimal level of agricultural output, income and prices, and second, even it that level existed, it would not be possible for agriculture to remain at that point for an extended period.

In terms of Josling's taxonomy, this particular framework of analysis, with an apolitical view of agriculture, suggests there is little the government can do other than continuing to intervene and attempting to correct for the "structural defects" in the food and fibre system. At

present, this intervention is in the form of direct price supports, acreage set-aside incentives, export enhancement programs, etc. There is an on-going debate about the desirability of implementing alternative income-stabilization instruments, and possibly introducing separate farm policies and programs for "large" as opposed to "small" farms. While other instruments for intervening undoubtedly exist, this analysis suggests a stable equilibrium with adequate returns to resources will be difficult, if not impossible, to maintain over time, regardless of the instrument(s) chosen.

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Appendix 1. Derivation of an Offer Curve

Assume a specific utility function $U^a = AN$ for the agricultural sector, and technology and factor endowments such that $A_e^a = f(K^a, L^a)$ and $N_e^a > 0$. Then the agricultural sector's maximization problem becomes (with notation as defined in the text):

$$\max_{\{A,N\}} \; U^a \; = \; AN + \lambda(pA + N - pA_e^a - N_e^a) \tag{A.1}$$

Hence,
$$U_A^a \; = \; N + \lambda p = 0 \tag{A.2}$$
$$U_N^a \; = \; A + \lambda = 0 \tag{A.3}$$
$$U_\lambda^a \; = \; pA + N - pA_e^a - N_e^a = 0 \tag{A.4}$$

Combining (A.2) and (A.3) yields: $A = N/p$ \hfill (A.5)

which is equivalent to the ordinary demand curve for A (abstracting from population and income). Next substitute (A.5) into (A.4),

$$A = 0.5\{A_e^a + (A/N)N_e^a\}. \tag{A.6}$$

This is not an offer curve, but a "consumption indifference" curve. To obtain the offer curve use:

$$A = A_c^a = A_e^a - A_x^a \quad \text{and} \tag{A.7a}$$
$$N = N_c^a = N_e^a + N_m^a, \tag{A.7b}$$

where c refers to quantity consumed and x and m refer to exports and imports. Since the offer curve is drawn in quantities traded space, express (A.6) in these terms. After rearranging, that equation becomes

$$A_x^a = 0.5\{A_e^a - [(A_e^a - A_x^a)N_e^a]/(N_e^a + N_x^a)\} \tag{A.8}$$

Equation (A.8) is the reciprocal *supply* and *demand* or offer curve for the agricultural sector. Note that with the utility function used here, it has to be assumed that $N_e^a > 0$; i.e., the agricultural sector produces at least some non-agricultural products (if this causes difficulty, one may conceive of agricultural and non-agricultural regions trading with each other). If $N_e^a = 0$, then the offer curve degenerates to $A_x^a = 0.5\{A_e^a\}$. Because agricultural sector preferences are completely symmetric, exactly half of the agricultural output is traded for nonagricultural products $A_x^a = A_c^a = 0.5A_e^a$.

Endnotes

1. The same is true in Tweeten's 1979 book, *Foundations of Farm Policy*.

2. Alternatively, these sectors can be construed of as agricultural and non-agricultural regions of the U.S. The non-agricultural sector or region includes foreign demand.

3. Small letters ($i=a,n$) are used to index the sector while large letters ($I=A,N$) refers to stocks of output from each sector. The analysis abstracts from the possibility that some resources in the two sectors are owned by the same economic entity, and from off-farm employment as well as part-time farming activities. These abstractions do not change the facts about elasticities that are discussed below and that are central to the analysis.

4. Consumption and production functions are assumed to exhibit standard properties.

5. Spending on consumer items is likely to be minor relative to purchases of agricultural inputs in any given year, and thus should not affect production decisions. This assumes, in other words, that inelasticity of the agricultural sector OC is preserved even after considering purchases of consumer goods.

6. A comprehensive treatment of instability can be found in Newbery and Stiglitz.