``

Food storage, multiple equilibria and instability: why stable markets may become unstable during food crises

John Mackinnon

WPS/99-1

January 1998

Abstract:A temporary-equilibrium model replicating institutional features of low-income agricultural economies is developed. In this model, food is held as an asset; because food production is relatively volatile, those with negative temporary income are net buyers of food. When food is the only asset, asset effects are likely to reduce the price-elasticity of the demand for food and can make it tatonnement-unstable, because the distributional effects of food price rises increase savings. When money is introduced, instability remains possible because a permanent rise in the price level increases risk, inducing substitution from money into food stocks.

JEL numbers D51 (exchange and production economies), D52 (incomplete markets), Q11 (aggregate agricultural supply and demand), Q12 (macroeconomic analysis of farms)

Keywords: general equilibrium, temporary equilibrium, instability, precautionary saving, famine

Correspondence: 31G Champion Hill, London SE5 8BS, UK Centre for the Study of African Economies, Institute for Economics and Statistics, St Cross Building, Manor Road, Oxford, OX1 3UL, UK, e-mail: jwm1962@aol.com

Note: This paper was written while I was a Research officer at the Centre for the Study of African Economies, which is a Designated Research Centre of the ESRC. I have benefited from discussions with Daniel Ayalew of joint work in progress on the macroeconomics of food shocks in Ethiopia. I am also grateful to Richard Mash, Andrew McKay, Simon Mohun, and seminar participants at CSAE for comments. All errors are mine.

1 Introduction

The price of food is an emotive variable; during famines, observers often suggest that traders are driving the price of food up and therefore worsening hunger. There are at least three reasons why food markets may produce price movements which are not socially optimal. First, food markets may not be competitive; the dynamics of food prices where traders are monopolistic will depend on the liquidity of consumers, and it might be in a monopolist's interest to produce sharp spikes in the food price if consumers cannot afford to wait. Secondly, even in competitive spot markets, if futures markets do not exist, traders may wrongly forecast the food price, causing excess price volatility (Ravallion (1985a,b)). Thirdly, where insurance market do not exist, increases in the price of food transfers real income from net buyers of food who may be those with low temporary incomes; this increases the risks facing households, exacerbating the inefficiency caused by the absence of insurance markets (Newbery 1989a).

Prices may therefore be excessively volatile in two senses: they may be more volatile than they would be in an Arrow-Debreu model; or they may have more volatility than would be socially optimal. In either sense, volatility is compatible with the existence of a stable and unique equilibrium within each period. Although instability is known to depend on strong assumptions, the literature on price volatility in food markets has mostly worked with stable and unique equilibria; an exception is Bardhan (1969), who suggests that increases in the price of food transfer real income towards the worse-off, who have a higher marginal propensity to consume food.

This paper explores the consequences for general equilibrium of the fact that food plays multiple roles in many agricultural economies; as well as being a consumer good, it is both store of value and insurance good. The paper's main objective is to examine whether these multiple roles can generate instability. In a temporary equilibrium where food is the only asset, anything which increases savings will increase the asset demand for food. Now an increase in the food price will transfer real income from net buyers of food. If net buyers of food are more likely to be liquidity-constrained than other households, this effect no the magnitude of savings tends to make the demand curve for food steeper than it would otherwise be and can cause tatonnement-instability. Where other assets exist, portfolio composition effects also matter. these can also be destabilising, because if an increase in the food price is expected to persist, the risks facing households increase, causing them to substitute into the safe asset, which is food.

The model developed here reflects four institutional features of low-income agricultural economies. First, food production is both an important source of income and relatively volatile. Secondly, households which produce food may find themselves buying food when they run short. Thirdly, food stocks are an important part of households' liquid assets (especially where inflation or insecurity has reduced access to different assets). Fourthly, risk is not efficiently pooled across the economy, so that there are some liquidity-constrained and some non-constrained households within the same period. (See Alderman and Paxson (1992) for a survey of the literature on the extent to which households are able to insure themselves by informal means against income shocks).

The analysis of consumer choices when consumers cannot borrow and face stochastic incomes has been developed, with particular reference to developing countries, by Deaton (1989 and

1991). Deaton's analysis is mostly partial-equilibrium, though he uses the theory to provide an interesting preference-based explanation of class-based theories of savings, which are at the heart of some dualist models of economic development. This paper embeds Deaton-style consumers in a temporary-equilibrium exchange economy with two commodities. In the first model, food is the only asset, but a second asset called 'money' is then introduced. It is shown that the savings effect described above, in the case without money, will make the demand curve for food steeper, and that this effect can generate instability, particularly when many agents are liquidity-constrained; so an economy which usually functions smoothly may become unstable in bad periods.

The empirical consequences of tatonnement instability and multiplicity are unclear, since tatonnement is not supposed to happen in real time. If instability were proven, this might justify price interventions in certain cases, but it is unlikely in practice that these effects could be clearly enough established or quantified to justify such interventions given the enormous risks of policy error. More robust policy implications are the benefits of price-stabilising trade liberalisation, the benefits of improved access to consumption credit for households, and the benefits of a system of well-funded and relatively risk-neutral traders; it is households' risk-aversion, not traders' speculation, which generate instability in this model. (Speculation in the sense of Tirole (1982), which is purchase with the intention of resale, plays no part in this model).

However, the importance of violent movements in food prices is illustrated by the 1984-5 famine in Ethiopia. Between February 1984 and August 1985 the price of cereals in the Addis Ababa CPI, relative to the CPI as a whole, increased by 95%. This increase accompanied a drastic fall in the value of livestock, which meant that people who were trying to convert livestock into food faced a drastic worsening of their terms of trade. While prices in some regions were increased by obstacles imposed to the free movement of food, the increase in the price in Addis Ababa is less likely to be explained mainly by this, not least because the authorities needed to insulate people in Addis Ababa from the worst effects of the famine for their own survival. Faced by such drastic movements in prices, it is important to ask whether theory suggests these should be interpreted as movements along a demand curve caused by severe contractions in supply, or whether instabilities in markets are likely to play a part. It is also worth nothing that such drastic price movements are unparalleled in the rest of the Addis Ababa CPI since 1963 when the series started. If the economy's behaviour changes during crisis, this has real practical importance.

Before presenting the model, I consider some methodological issues. The explicit modelling of the household's intertemporal decisions distinguishes this paper from previous analyses by Newbery (1989b) and Ravallion (1987), both of whom introduce simplifying assumptions which ensure that demand curves slope downwards, and from Bardhan's one-period model (Bardhan (1969)). For other discussions of stability in temporary equilibrium see Arrow and Hahn (1971) and Stahl (1987).

The method of temporary equilibrium involves some potentially controversial assumptions about expectations. When prices are called out by the auctioneer, agents are assumed to form expectations about future prices conditional on this price holding in the current period. There is an element of arbitrariness, because this price need not itself be an equilibrium price, so that the notion of 'rational expectations', which is typically conditioned on equilibrium, is inapplicable to a tatonnement process (the problem would not arise in an Arrow-Debreu model because the auctioneer calls out vectors of current and future prices). I follow Grandmont (1988) and others in imposing a simple structure where a price change is assumed either wholly temporary or wholly permanent.

It might be argued that if expectations are rational, then the economy will converge instantaneously to equilibrium, making tatonnement unnecessary. There is a good practical reason for rejecting this argument. The economy could converge without tatonnement, or some other out-of-equilibrium process, only if all agents could instantaneously observe aggregate production. In fact, even the authorities often have difficulty estimating what is happening to food production, a factor which played a large role in the Chinese famine of 1959-61 (Lardy 1983) and which has motivated the development of early-warning systems for famine detection. Given that food production is the sum of millions of producers, each of whom faces considerable shocks which are imperfectly correlated across farmers, the out-of-equilibrium process plays an essential informational function, as in Hurwicz (1969). Instability of a tatonnement process in this context is potentially serious.

The paper is organised as follows. Section 2 presents the model without cash and with only idiosyncratic risk, allowing the simplification of constant-price equilibria. Equilibrium is described and its welfare properties briefly considered. Section 3 establishes the conditions under which equilibrium within the period will be unstable under temporary and permanent price changes in this simple case, and compares the results to the model without storage and the model with complete markets (both of which are likely to be stable). The results are extended by considering the dynamics of the system in Section 4, by introducing aggregate risk in Section 5, and by introducing an alternative asset called 'money' in Section 6. Section 7 concludes.

2 A model of temporary equilibrium in food markets, with constant aggregate supply

I consider a temporary-equilibrium exchange economy with no futures or contingent markets. There are *N* agents (a large number), indexed by *i*, and two commodities, food (indexed *f*) and nonfood (indexed *n*); food differs from nonfood in that it is storable and not a luxury and its production is random, whereas nonfood is nonstorable, is not a necessity, and its production is constant in each period. Agents live for ever and can transfer value between periods only by storing food; if they run out of food, they become liquidity-constrained. Within the period, agents trade food and nonfood with each other in a perfectly competitive market.

All agents produce both commodities; production, in this section, is assumed independent across agents and periods. Hence, with very many agents, there is no volatility in aggregate output; aggregate risk is introduced in Section 5. Writing y_{ijt} for production of commodity *j* by agent *i* in period *t*,

$$y_{ift} \sim D_{yf}(\overline{y}_f, \sigma_f^2) \quad for\ all\ i\ and\ t \tag{1}$$

$$cov(y_{aft}, y_{bft}) = 0\ for\ a \neq b,\ all\ t \tag{2}$$

$$cov(y_{ift}, y_{ift+n}) = 0 \ \ for\ \ n \neq 0,\ \ all\ \ i,t \tag{3}$$

$$y_{int} = \overline{y_n}\ \ all\ \ i,t \tag{4}$$

where D_{yf} is some well-defined probability distribution with finite mean and variance. Thus food output is random whereas nonfood output is constant (this is a simple way of representing the empirical generalisation that agricultural output fluctuates more than that of other sectors). From the central limit theorem, as the number of agents increases, not only the mean of the within-period population distribution of output across agents, which will be written D_{yft}^{pop}, but all other moments of the population distribution approximate increasingly closely to the moments of D_{yf}. In this section, the two distributions are assumed to be the same, allowing constant price equilibria.

The agent's availability of commodity j is defined as follows:

$$z_{ijt} = y_{ijt} + \delta_j S_{ijt-1} \tag{5}$$

where δ_j is the rate of survival of commodity j, and S is end-of period-stocks. It is assumed throughout that only food is storable:

$$\delta_n = 0 \tag{6}$$

$$1 > \delta_f > 0 \tag{7}$$

As the horizon moves to infinity the long-run expectation of food stocks is bounded from above by the stocks that would accumulate if the value of mean food production were stored in each period (for any finite initial stock):

$$\lim_{t\to\infty} \Sigma_i E_t S_{ift+n} \leq \left(\frac{1}{1-\delta_f}\right) \Sigma_i E(y_{ift}) \tag{8}$$

The budget constraint is given by

$$B_{it} \equiv p_{ft}(\delta_f S_{ift-1} + y_{ift}) + p_{nt} y_{int} - p_{ft}(x_{ift} + S_{ift}) - p_{nt} x_{int} = 0 \tag{9}$$

where x_j denotes consumption of commodity j. B_{it} (the gap between income and its uses in consumption and savings) is zero in equilibrium but its partial derivative with respect to the food price, holding consumption constant, is important below and is given by net sales of food: these will be written Q_{it}

$$\frac{\delta B_{it}}{\delta p_f} = y_{ift} - x_{ift} - (S_{ift} - \delta_f s_{ift-1}) \equiv Q_{it} \tag{10}$$

Agents choose consumption of all commodities to maximise discounted expected utility (assumed to have the same functional form for different agents),

$$E_t \sum_{n=0}^{\infty} \rho^n u(x_{ft+n}, x_{nt+n}) \tag{11}$$

where the subjective discount rate is given by (1-ρ/ρ) and intra-period utility is increasing and concave in both its arguments:

$$u_{it} = u(x_{ift}, x_{int}),\ u_f > 0,\ u_n > 0,\ u_{ff} < 0.\ u_{nn} < 0,\ u_{ff}u_{nn} < u_{fn}^2 \tag{12}$$

The objective function (11) is maximised subject to the budget constraint above and the liquidity constraint

$$x_{ift}, S_{ift}, x_{int} \geq 0 \ \ all \ \ t \tag{13}$$

In performing this maximisation, agents use the subjective probability distribution of future prices

$$g(p_{ft+1}, p_{ft+2} \ldots | p_{ft}) \tag{14}$$

In general, many assumptions can be made about the form of this function, and all its moments may be important. Below, I follow Grandmont (1988) in studying a limited family of forms of *g( )*.

I impose some restrictions on preferences. Define total nominal consumption x as

$$x_{it} = p_{ft}x_{ift} + p_{nt}x_{int} \tag{15}$$

The intertemporal additive separability of preferences implies that we can model the consumer as first allocating consumption intertemporally and then allocating consumption within the period (Deaton and Muellbauer 1980); the second stage can then be modelled by taking nominal expenditure as fixed. I assume that at all times and for all price vectors both the share of nonfood and the marginal propensity to consume nonfood are not decreasing in total consumption (food is not a luxury). If food were a luxury, instability would become even more likely in this model.

$$0 < dx_{ift}/dx_{it} \tag{16}$$

$$0 < dx_{int}/dx_{it} \tag{17}$$

$$d^2x_{int}/dx_{it}^2 \geq 0,\ d^2x_{ift}/dx_{it}^2 \leq 0 \tag{18}$$

$$\delta x_{int}/\delta x_{it} \geq x_{int}/x_{it} \tag{19}$$

Finally, I assume that as a first-order approximation in the neighbourhood of equilibrium, both utility and the marginal utility of expenditure depend only on the level of real expenditure, using equilibrium prices to evaluate real expenditure. Formally, for prices p_f and p_n near equilibrium prices p^*_f and p^*_n, it will be assumed that

$$u_{it} = v(C_{it}), \quad \frac{\delta u_{it}/\delta x_{ift}}{p_{ft}} = \frac{\delta u_{it}/\delta x_{int}}{p_{nt}} = v'(C_{it}) \qquad \textbf{(20)}$$

where C_{it} is current consumption valued at constant prices near equilibrium:

$$C_{it} = p_f^* x_{ift} + p_{nt}^* x_{int} \qquad \textbf{(21)}$$

and $v(C_{it})$ is the utility function defined in terms of total real consumption. (20) imposes some restrictions on the shape of Engel curves. For instance, if intra-period utility is additively separable in food and nonfood, then it implies that Engel curves are linear; otherwise the marginal utility of income will change when compensated price changes occur, and if food consumption is concave in income, then an increase in the relative food price will increase marginal utility for a given level of total real expenditure. This will tend to increase consumption in the current period, which works against the distributional savings effect which is identified below. While linearity of the Engel curve is restrictive, Lipton (1982) suggests it may be characteristic of 'ultra-poor' rural households. However, the assumption does not restrict the degree of substitutability; Leontief preferences can justify it as well as Cobb-Douglas preferences.

Temporary equilibrium, expectations and steady state

With no loss of generality, in the absence of money, I will consider changes in the price of food holding the price of nonfood constant, in the neighbourhood of an equilibrium price p^*_f. In a tatonnement process, agents make offers to trade based on the assumption that the price called out will be the equilibrium price and the probability distribution of prices in future periods, g. Hence the form of g is crucial. In what follows, I consider two alternatives. In the first, the following event is assigned probability 1:

$$p_{ft} = p_{ft+n} \; for \;\; all \;\; n \geq 0 \qquad \textbf{(22)}$$

This case corresponds to 'unit-elastic expectations' in the sense of Hicks (1946). A change to p_{ft} will be termed 'permanent'; the permanence is a property of the subjective probability distribution, not of the economy-wide equilibrium.

In the second case, the following event is expected with probability 1:

$$p_{ft+n} = p^* \; for \;\; all \;\; n > 0 \qquad \textbf{(23)}$$

Here expectations are totally inelastic in Hicks' sense and the price change will be termed 'temporary'.

Conditional on the form of g, demand for each commodity in the neighbourhood of p^*_{ft} is a function of present prices p_{ft} and previous endowment:

$$x_{ift} = x_{ift}(p_{ft}, \; p_{nt}, \; z_{ift}) \qquad \textbf{(24)}$$

$$x_{int} = x_{int}(p_{ft},\ p_{nt},\ z_{ift}) \qquad \textbf{(25)}$$

$$S_{ift} = S_{ift}(p_{ft},\ p_{nt},\ z_{ift}) \qquad \textbf{(26)}$$

Market equilibrium reflects the summation of demand curves:

$$\Sigma_i x_{int} = \Sigma_i y_{int} \qquad \textbf{(27)}$$

$$\Sigma_i x_{ift} + \Sigma_i S_{ift} = \Sigma_i y_{ift} + \Sigma_i \delta_f S_{ift-1} \qquad \textbf{(28)}$$

Walras's Law holds, so that either of these equations implies the other.

Constant-price equilibria

For the remainder of this section, I concentrate on constant-price equilibria. We can understand such an equilibrium as follows. At any time, there is a population distribution of endowments across agents; this can be defined by a distribution function $D^{pop}{}_{zft}$. Since all agents are symmetric in all respects apart from their current endowments, this distribution gives a complete set of information about the state of the economy, and there will be a mapping from this function to one or more equilibrium prices p^*_f. Individual endowments move according to the stochastic difference equation

$$z_{ift} = \delta_f S_{ift-1}(z_{ift-1}) + y_{ift} \qquad \textbf{(29)}$$

where the demand function for stocks is determined by (26) under some assumption about the form of g. The summation of these stochastic difference equations generates a difference equation for the population distribution. Because there are very many agents, the proportion of agents with a given level of stocks and a given level of production in the current period becomes perfectly predictable. As a result, although the individual difference equations are always stochastic, the population difference equation can be treated as deterministic:

$$D^{pop}_{zft} = D^{pop}_{zft}(D^{pop}_{zft-1}) \qquad \textbf{(30)}$$

Thus the shape of the population distribution function in one period is a deterministic function of its shape in the previous period. A constant-price equilibrium is an equilibrium associated with a population distribution of stocks which is a fixed point of the mapping (31); i.e.

$$D^{pop}_{zft}(D^{pop}_{zft-1}) = D^{pop}_{zft-1} \qquad \textbf{(31)}$$

If (31) holds, an equilibrium price in the current period will remain an equilibrium in the following period. Provided that the economy does not jump between equilibria and that all trades occur in equilibrium, this price will therefore persist for ever. Neither of the expectations functions (22) and (23) will therefore be refuted in equilibrium; in this sense they are model-consistent inside though not outside equilibrium. We can imagine that the economy has settled on the steady-state probability distribution D^{pop}_{zft} for so long that prices have been steady since time immemorial.

Given the prevailing price p^*_f, there can be no more than one steady-state distribution D^{pop}_{zft}. This follows from the observation that individuals' stocks follow a first-order autoregression:

$$z_{ift} = S_{ift}(z_{ift-1}) + y_{ift} \qquad \textbf{(32)}$$

This autoregression is bounded by zero and its expectation is bounded from above by (8). The covariance between periods decays over time. Hence the conditional distribution of this function will converge to some unique steady-state distribution as the horizon extends into infinity. Given that individuals' histories are not correlated, the population distribution will have exactly the same form as the 'horizon' value of the individual distribution of endowments:

$$\lim_{n\to\infty}(D_{izft+n}|z_{ift}) = D_{zf}^{pop} \ for \ all \ z_{ift} \qquad \textbf{(33)}$$

Dynamics of individual consumption in constant-price equilibria

In what follows, the form of the functions (24-26) is important. Deaton (1989) and (1991) analyses the intertemporal behaviour of an optimising consumer under liquidity constraints, and the current problem adapts Deaton's approach by introducing relative prices. In this section I analyse $C(z_{ift})$ holding p_f and p_n constant.The Euler equation takes the simple form

$$v^{/}(C_{it}) \geq \rho\delta_f E v^{/}(C_{it+1}) \qquad \textbf{(34)}$$

$$S_{ift} \geq 0 \qquad \textbf{(35)}$$

with complementary slackness. First, consumption is increasing in z_{ift} for all values of z_{ift}, for the following reason. An increase in z_{ift} relaxes liquidity constraints and must increase consumption in some state of the world. However, if some such state of the world is possible in some future period, then (from the concavity of the utility function and the Euler equation) consumption must increase in the preceding period. Backwards induction shows that consumption in the current period must rise.

The intertemporal pattern of consumption depends on the behaviour of marginal utility. One polar case which is useful for analysis, although unlikely to be realistic, is that of linear marginal utility. In this case expected marginal utility is given by the marginal utility of expected consumption: it can then be seen from (34) that expected consumption falls over time, at an increasing rate, until stocks are exhausted, although the actual course may be interrupted by positive income shocks.

$$v'(C_{it}) = \rho\delta_f E_t v'(C_{it+1}) = \rho\delta_f v'(E_t C_{it+1}) < v'(E_t C_{it+1}) \Rightarrow C_{it} > E_t C_{it+1} \qquad \textbf{(36)}$$

Agents are therefore likely to experience periods when liquidity constraints actually bind. In these periods, consumption will usually be expected to rise; aggregate consumption must be stationary so that the expected fall characteristic of the liquid is offset by the expected rise for the liquidity-constrained.

A second case, which is more realistic as a characterisation of preferences (Deaton (1989) and (1991)), is that the third derivative of utility is positive. Two forms of solution are now possible, depending on the exact form of the utility function. First, as with linear marginal utility, it is possible that expected consumption and stocks will fall until stocks are exhausted. However, it is also possible that for some value of C and z_{ift}, (34) holds with equality with no fall in expected consumption. In this case stocks are expected to stabilise at a positive level. Because individual consumption in this model is a mean-stationary process with no memory before the previous period, there can only be one such level of stocks. In extreme cases, for instance where the marginal utility of consumption goes to infinity at a level above the consumption guaranteed by the lowest possible realisation of output, no agent will ever completely run out of stocks. Where the actual level of stocks is expected to increase, expected consumption must also be increasing.

In what follows, I assume that some agents do sometimes run out of stocks, and the paper's main results stem from the resulting asymmetry between constrained and unconstrained agents. The alternative assumption can generate similar behaviour through precautionary effects which will mean that the increased variance of real income caused by an increase in the food price will induce precautionary savings, but the analysis is more complex.

The distribution of net sales in the following period, conditional on stocks, is also important in what follows. Net sales of food are in general a weakly convex function of consumption, because nonfood is not a necessity. However, net sales of nonfood must sum to zero across the population and must therefore be mean-stationary for the individual in steady state (because the individual distribution converges to the population distribution as noted above). Since for the liquidity-constrained net sales are expected to increase, for the non-liquidity-constrained they must be expected to fall where stocks are above a certain level.

The other important feature of the optimal solution is the covariance of different variables in future periods. Note that the population distribution is constant and that the individual moves between different points on that distribution over time. Agents differ only in one dimension: the amount of food they have. Hence the covariance between food stock and any of the variables over time for the individual will have the same sign as the within-period population covariance. The demand functions (24-26) are deterministic functions of the agent's endowment, which is itself a stochastic variable, and of prices, which are assumed constant. Under constant prices both x_{if} and x_{in} are positively related to C_{it}. From the budget constraint, it follows immediately that since y_{in} is assumed constant, net sales of nonfood are negatively related to consumption. Hence net sales of food must be positively related to consumption, and negatively to the marginal utility of consumption. It is also useful to consider net sales of food as a proportion of total consumption. Note that net sales of food are related to the share of nonfood in consumption as follows:

$$\frac{Q_{it}}{x_{it}} = \frac{p_f/p_n(x_{in}-y_{in})}{x_{it}} = \frac{p_f}{p_n}\frac{x_{in}}{x_{it}} - \frac{p_f}{p_n}\frac{y_{in}}{x_{it}} \tag{37}$$

Since y_{in} is constant, this fraction must increase with C provided that the nonfood share is nondecreasing in total consumption, as was assumed above.

These relations operate throughout the functions (24-26) for given prices. They imply the following signs for the covariance between net sales and the level of consumption, both for the population distribution and for the conditional distribution of individual next-period marginal utility given z_{it} and S_{it}:

$$cov(v'(C_{it}) \ , \ Q_{it}) < 0 \tag{38}$$

$$cov(v'(C_{it}), \ Q_{it}/x_{it}) < 0 \tag{39}$$

Since prices are fixed in equilibrium, exactly the same covariances apply to real consumption valued at the equilibrium price. These results are used below.

Welfare properties of equilibrium

The absence of insurance implies that the economy is not Pareto-efficient; a Pareto-efficient economy would completely smooth individuals' consumption, since there is no aggregate variability. Intuitively, the introduction of storage may be expected to improve social welfare, but this is not necessarily the case. If storage is possible, it will be a much rarer event that individuals are liquidity-constrained, and in this respect people will be better off. However, the outcome for an individual who is liquidity-constrained is actually worse with storage, because the price of food is higher and hence their net purchases of nonfood occur at less favourable prices for them. Hence the distribution of expenditure across the population within the period with storage will not stochastically dominate the distribution that occurs without storage; and it is not certain social welfare will be higher.

3 The stability of temporary equilibrium

After the above preliminaries, we can address the main question of the paper: tatonnement stability. During tatonnement, traders base their offered trades on the assumption that the currently called price is the equilibrium price because the trade will take place only if the prices are in fact equilibrium prices. The stability of equilibrium is now investigated by perturbing the price, under the alternative models of price expectations (22) and (23). The food and non-food market equilibrium conditions (27-28) imply each other, so local stability can be explored simply by examining the slope of the demand curve for nonfood. A rise in the food price will reduce consumption of food, but it will also increase demand for foodstocks.

3.1 The cases of no-storage and complete markets

Before modelling the economy with storage, it is useful to note that equilibrium in the no-storage economy would be locally stable and unique. For the no-storage equilibrium where $\delta_f = 0$, we can use the Slutsky decomposition

$$dx_{in}/dp_f = \delta x_{int}/\delta p_f|_{uconstant} + dx_{in}/dC(y_{ift} - x_{ift}) \quad \textbf{(40)}$$

The first term is positive for all agents. The second term is positive for those who are net sellers of food. Net sales of food sum to zero over the economy in equilibrium, whereas the marginal propensity to consume nonfood is equal or higher for net buyers than for net sellers of nonfood. The aggregate income effect must therefore be nonnegative, and hence the equilibrium is locally stable. Local stability of equilibrium guarantees uniqueness because demand and supply functions are continuous; if there were more than one equilibrium, one would have to be unstable.

The case of complete futures and contingent markets is not analysed here. Since within-period income effects reinforce substitution effects, the intertemporal equilibrium is also likely to be stable, though I have not been able to eliminate freak instabilities arising because of intertemporal substitution. Certainly, the reasons to fear instability which are discussed below in the case without credit and insurance would not arise if all markets existed.

3.2 A permanent increase in the food price

Returning to the main case, I now consider the implication of an increase in the price of food under the expectations function (22) . We are interested in the sign of the following expression:

$$\Sigma_i \; dx_{int}/dp_f \quad \textbf{(41)}$$

where the time subscript is omitted because we are considering a permanent perturbation of the price. I assume that the economy starts in a steady state (note that this implies that no change in price is anticipated).

Each element in the sum will be positive if nominal consumption does not fall for any agent (which is reasonable) and the uncompensated elasticity of net demand for food for each individual is greater in magnitude than -1 for all agents. A sufficient condition for this is that the uncompensated elasticity of gross demand is in magnitude larger than -1 for all agents (Arrow and Hahn (1971) observe that the equivalent condition for aggregate gross demand is equivalent to the aggregate gross substitute property in general).

From now on I will assume that substitution effects, although of normal sign, are (at least for some agents) not strong enough to guarantee the positivity of each term in (42). In this case we proceed by decomposing (42) further. Expressing the sum as the product of the population size and the mean of the distribution, we get

$$\Sigma_i \frac{dx_{int}}{dp_f} = \Sigma_i \frac{\delta x_{int}}{\delta p_f}\Big|_{C_{it}\ const} + \qquad \textbf{(42)}$$
$$N\ cov^{pop}(dx_{int}/dC_{it},\ dC_{it}/dp_f) + E^{pop}(dx_{int}/dC_{it})\Sigma_i(dC_{it}/dp_f)$$

The first two terms are within-period substitution and income effects, and are non-negative. It is immediately clear that dC_{it}/dp_f is positively related to Q_{it}, and the relation between Q_{it} and the marginal propensity to consume nonfood is established by (18). The third term, however, represents the savings effect. The main result of this section is that this term is likely to be negative and hence (42) cannot be signed. $E^{pop}(dx_{int}/dC_{it})$ is definitely positive; the question is the sign of the effect on aggregate real consumption, $\Sigma_i dC_{it}/dp_f$.

$$\Sigma_i \frac{dC_{it}}{dp_f} \qquad \textbf{(43)}$$

The sum (43) is taken over some liquidity-constrained consumers and some liquid ones. Because the liquidity-constrained agents are the poorest, they have the highest net sales of food. Net sales of food sum to zero over the population. So we have

$$\Sigma_i Q_{it} = 0, \quad \Sigma_{z_{it+1}=0} Q_{it} < 0, \ \Sigma_{z_{it+1}>0} Q_{it} > 0 \qquad \textbf{(44)}$$

The examination of this sum comes in two stages. First, for the liquidity-constrained, it is trivial that at the margin spending changes by the change in current income:

$$dC_{it}/dp_f = Q_{it} \qquad \textbf{(45)}$$

For the non-constrained I prove the following proposition in the annex. **Proposition One: For a non-liquidity-constrained individual whose net sales are above a certain level, if v(C) exhibits linear marginal utility, constant absolute risk aversion, or constant relative risk aversion,**

$$dC_{it}/dp_f < Q_{it} \qquad \textbf{(46)}$$

The reason for (46) is that people who are currently net sellers of food do not expect to be selling food for the indefinite future; the price increase, although itself permanent, contributes to temporary income and is therefore partly saved. Now note that net sales sum to zero. Summing across classes of agents for whom (45) and (46) hold, we are likely to have

$$\Sigma_i \frac{dC_{it}}{dp_f} < 0 \tag{47}$$

The only caveat here is that there could be some agents for whom

$$dC_{it}/dp_f > Q_{it} \tag{48}$$

This could hold for agents who are net buyers of food but are liquidity-constrained, and who therefore smooth their permanent income loss just as net sellers of food smooth their permanent income gain. Nonetheless, it is clear that at least for some distributions of income - for instance where all net buyers of food, but not all net sellers, are liquidity-constrained -(47) will hold.

If (47) holds, then the sign of (41), the slope of the demand curve, becomes ambiguous, depending on the relative strength of within-period income and substitution effects on the one hand and the savings effect on the other. There is no presumption about the relative strength of the effects making for stability and instability because they arise from different factors; the income and substitution effects depend on the shape of the utility function and the proportion of the population which is liquidity-constrained. Provided that the liquidity-constrained do reduce their nonfood consumption when the price of food rises, the downward slope of the demand curve is a serious possibility for at least some distributions of stocks.

3.3 A temporary price increase

We now model (41) under the expectation function (23). There are two main differences from a permanent price change. Because the change is expected to be temporary, the temporary component of the income shock is larger and the permanent component smaller. So those agents who are not liquidity-constrained have lower propensities to consume the extra income generated than in the permanent case, whereas those who are liquidity-constrained still have a unitary marginal propensity to consume. The savings effect will therefore be absolutely larger than in the permanent case. Secondly, the temporary food price rise reduces the price of nonfood in the current period relative to all other prices, encouraging consumption. Consumers therefore substitute not only from food in the current period but also from food and nonfood in the subsequent periods into nonfood in the current period. However, this effect works only for those who are not liquidity-constrained. Formally, we can exploit the fact that a temporary price change has no direct impact on future periods' budget constraints to decompose (41) further as follows:

$$\Sigma_i \frac{dx_{int}}{dp_{ft}}\Big|_{p_{ft_1} const} = \Sigma_i \frac{\delta x_{int}}{\delta p_{ft}}\Big|_{C_{it} const} + \Sigma_i \frac{\delta x_{int}}{\delta C_{it}} \frac{\delta C_{it}}{\delta p_{ft}}\Big|_{B_{it} const} + cov^{pop}\left(\frac{\delta x_{int}}{\delta C_{it}}, \frac{\delta C_{it}}{\delta B_{it}} \frac{\delta B_{it}}{\delta p_f}\right) + E^{pop}\left(\frac{\delta x_{int}}{\delta C_{it}}\right) \Sigma_i \left(\frac{\delta C_{it}}{\delta B_{it}} \frac{\delta B_{it}}{\delta p_f}\right) \tag{49}$$

The first two terms here are intra- and inter-temporal substitution effects. The third term is the aggregate within-period income effect, which arises from the redistribution of expenditure within the period towards the better-off. The intratemporal substitution and income effects are positive as before; the intertemporal effect is new, and also positive. The fourth term is the savings effect; as before, this will usually be negative. Moreover it will in general be larger than before, because dC/dp_{ft} will be smaller than in the temporary case for liquid agents but will be unchanged for illiquid agents, for whom it is negative. Hence the sign of the whole expression is ambiguous.

3.4 The implications of instability for the multiplicity of equilibrium

If there is instability, multiple equilibria become possible. Since the demand and supply functions are continuous, a locally unstable equilibrium cannot be unique if demand for either commodity moves to infinity as the price falls to zero. This is usually the case in a two-commodity economy where both goods are normal, because as the price of one commodity falls, the wealth of the net buyer of this commodity rises and eventually the income effect on this group dominates the response of the economy. In the current case, however, an increase in the price of food, while increasing the wealth of net sellers, also increases the variance of future income; this can induce precautionary saving and if this effect were strong enough it would dominate the wealth effects. Hence, while the likeliest shape for the demand curve, under either a temporary or permanent price change, is therefore as shown in figure 1 or figure 2; but the shape shown in figure 3 cannot be ruled out for a permanent price change.

4 The possibility of multiple steady states and multiple equilibrium paths

Multiple steady states

If there are multiple market-clearing prices, starting from a steady-state, an equilibrium price other than the previously prevailing one will not itself be a steady state, because it will cause a change in the level of stocks over time (since the demand for food stocks is increasing in the price of food). For multiple steady states, there would have to be more than one pair p^*, $D^{pop}(z)$ satisfying (31) and (23).

The dimensionality of the problem is considerably reduced by continuing to work with the expectations function (21), which will be rational in steady state though not along the adjustment path. I also simplify by assuming that the distribution of stocks in the economy can be adequately characterised by a single parameter, the aggregate level of stocks. Note that the aggregate level of stocks is not stochastic, although individual levels are. Consider now the space defined by S_{ft}, the aggregate level of food stocks, and p_f/p_n. As the relative price of food rises, food consumption falls (whatever happens to demand). Hence the level of stocks at which stocks are constant, defined by

$$\Sigma_i x_{ift} + \delta_f \Sigma_i S_{ift} = \Sigma_i y_{ift} + \Sigma_i S_{ift} \qquad \textbf{(50)}$$

rises. So the locus where foodstocks are constant will be upward-sloping in this space. Equilibrium in the nonfood market will be achieved on a different locus. If the equilibrium is tatonnement stable, then the locus will be downward-sloping because a reduction in wealth would be needed to offset the positive effects of the food price on demand for nonfood. If the equilibrium is tatonnement unstable, then the schedule can slope either way. Figure 2 shows a possible case where there are three steady states. Using this diagram, we can note that the economy is always on the locus of nonfood market equilibrium but will be moving towards the locus of constant stocks. We see, in this particular case, that all the equilibria are locally dynamically stable, though only two of them are tatonnement stable.

Perfect foresight paths

The paths described above involve errors in expectations along the path. I now ask whether there could be a perfect-foresight path leading from one equilibrium to another. Along such a path, the distribution of stocks varies. Price expectations are now conditional on the distribution of stocks, D_t^{pop}. Assume that for each such distribution there is a price p which agents expect to prevail with probability one:

$$p_t = p(D_{zft}^{pop}) \quad \textbf{(51)}$$

Now the function p will support a perfect-foresight equilibrium if each realisation of p gives within-period equilibrium given the current distribution $F^{pop}(z_{ft})$ and the correctly foreseen evolution of the distribution F^{pop}; this is described by the deterministic difference equation (31).

Consider now a case where the economy is in steady state, but where there are also equilibria for both temporary and permanent price changes, and there is a higher-price steady state with a higher level of food stocks. In this case, there is likely to be a rational-expectations path on which the price increases above the higher steady-state value and then falls back to the steady-state value as stocks accumulate; the initial price increase is thus party temporary and partly permanent, and the dynamics are shown in Figure 4.

5 Aggregate risk

In this section I relax the assumption that aggregate output is smooth; (2) is relaxed, but (1) and (3) continue to hold. Each agent's behaviour now depends on the joint distribution F of prices and their own output in future periods:

$$F(p_{t+1},\ y_{ft+1},\ p_{t+2}, y_{ft+2}, \ldots | p_t,\ y_{ft}) \quad \textbf{(52)}$$

This subjective distribution function is not assumed to be model-consistent. I will focus on the marginal distribution of prices, assuming that they do not affect the distribution of own output (in reality this may be restrictive: a price change might provide information for instance of a crop disease which has started to affect other farmers and can be expected to affect the agent themselves in future periods). A temporary price change is now easy to represent as a change in p_t without any change in the marginal distribution of future prices and output. A permanent change in price is harder to define in this context, and the proofs which were used above do not hold. Hence the analysis focuses on the temporary price change. The decomposition (60) remains valid, and the argument offered above continues to hold. However, there is one important difference: the proportion of the population who are liquidity-constrained will vary across periods.

The likelihood of being liquidity-constrained is negatively related to the household's available food supply (stock plus current output) and hence positively to net food purchases. In bad periods, there will be more people than usual liquidity-constrained. If a large proportion of those who are net purchasers of food are liquidity-constrained, then the savings terms in (49) will increase in magnitude, remaining negative. As a result, the probability that the expression (41) becomes negative increases. We therefore reach the important conclusion: **even if the economy is usually stable, it may become unstable in periods where food supply has fallen and many people are liquidity-constrained as a result.** As a result reliance on the market mechanism may become problematic just at the point where efficiency is most needed, because resources are most scarce.

However, in an extremely bad period even those who are selling food may themselves also be liquidity-constrained. In an extreme case no-one holds any stocks and hence the economy returns to the stable case where food is not storable.

6 Introducing money

In this section I introduce an asset called 'money' which can be used as an alternative store of value; it does not enter the utility function, however, and no transactions technology is modelled. The possible perversity of food demand arises from the multiple roles which food is playing. The introduction of money would remove the possibility of instability if food ceased to be held as an asset. However, in general this will not be the case, because in some periods food prices are expected to rise, and because food has better insurance properties than money, in the sense that its value rises in periods where aggregate income falls. The role of money (unlike food) in temporary general equilibrium has been central to macroeconomics ever since Keynes, Pigou and Hicks. The real balance effects which determine the stability of temporary equilibrium in the Keynesian case (see Tobin (1980) for a classic discussion) are similar to those which arise here, but one difference is that in this case it is money which has the superior rate of return and food which has the better insurance properties, because food decays but its price rises in bad periods, whereas Keynesian models usually assume that money has superior insurance properties to alternative assets. The insurance properties of assets are also important in the Lucas capital asset pricing model (Lucas 1978), and the equilibrium condition here is related to that in the Lucas model.

The quantity of money is exogenously fixed. The budget constraint becomes

$$B_{it} \equiv p_{ft}(\delta_f S_{ift-1} + y_{ift}) + p_{nt} y_{int} + M_{it-1} - p_{ft}(x_{ift} + S_{ift}) - p_{nt} x_{int} - M_{it} = 0 \qquad \textbf{(53)}$$

Market-clearing conditions (27) and (28) both hold; Walras' Law will imply that if these two conditions hold then the money market will be in equilibrium as well. It is now important to examine the effects of both p_f and p_n, because the system is no longer homogeneous in these two prices.

It is useful to focus on the conditions under which both money and food will be held. As before, I will focus on real consumption near equilibrium and use equilibrium prices to define a price index *P*:

$$P_t = \alpha p_{ft} + (1-\alpha) p_{nt} \qquad \textbf{(54)}$$

where the weights α and 1-α reflect the importance of food and nonfood in consumption in equilibrium. For simplicity, I assume that we can use the same price index for all agents; strictly this requires linear Engel curves. The holding of money requires:

$$v'(C_{it}) = \rho E_t \frac{P_t}{P_{t+1}} v'(C_{it+1}) \qquad \textbf{(55)}$$

and the holding of food requires:

$$v'(C_{It}) = \rho \delta_f E_t \frac{P_{ft}/P_t}{P_{ft+1} P_{t+1}} v'(C_{it+1}) \qquad \textbf{(56)}$$

Putting these together and expanding the products, we get

$$E_t \frac{P_t}{P_{t+1}} E v'(C_{it+1}) + cov(\frac{P_t}{P_{t+1}}, v'(C_{it+1})) = \delta_f E_t \frac{P_{ft}/P_t}{P_{ft+1}/P_{ft}} E_t v'(C_{it+1}) + \delta_f cov(\frac{P_{ft}/P_t}{P_{ft+1}/P_{t+1}}, v'(C_{it+1})) \qquad \textbf{(57)}$$

(57) provides the basis for the analysis of instabilities in the present case. We see immediately that no food would be stored in a constant-price equilibrium, because (68) could not be satisfied. Bad periods for the household, where the marginal utility of consumption is high, are correlated with bad periods for other farmers and hence high food prices; they are also likely to be correlated with the overall price level, as attempts by households to dissave in bad periods cause reductions in the value of the money supply. Hence that the covariance term on the left-hand side is likely to be negative while that on the right-hand side will usually be positive.

As in all the models considered above, there is an infinity of probability distributions of prices which can support temporary equilibrium, and it is necessary to restrict the range of prices considered, either by considering permanent and temporary price changes, or by restricting attention to the case of rational expectations.

I consider the following case. Starting from equilibrium, the absolute price level increases in all periods where food stocks are held. The resultant wealth effects would throw the nonfood market into excess supply unless the relative price of food also adjusted. Assume that the relative price of food also increases so that negative wealth effects and positive price effects on the demand for nonfood offset each other and the demand for nonfood is constant. Stability requires that this perturbation should reduce the demand for food and increase the demand for money.

Walras' Law in the current case gives

$$\begin{aligned} &\Sigma_i d(x_{if} + S_{if} + X_{\in} + M_{id})/dp_f = 0 \\ &\Rightarrow \Sigma_i d(x_{if} + S_{if})/dp_f = -\Sigma_i dM_{id}/dp_f \end{aligned} \quad \textbf{(58)}$$

Hence, without loss of generality, we can consider the demand for money. There are two effects; the increase in the price level in the current period causes an increase in the demand for money as consumption falls and the portfolio of assets demanded expands. But within the portfolio, there will be substitution between food and money. Consider the perturbation of equation (57). At a given level of portfolios, the price increase raises marginal utility in periods where the consumer is liquidity-constrained; these form the upper extreme of the probability distribution of the marginal utility of expenditure. Because this marginal utility increases only in the most extreme periods, it is possible that the covariance terms will increase more than proportionately with the mean of marginal utility. In this case induced portfolio substitution will be into rather than out of food. Depending on the relative strength of portfolio expansion and portfolio substitution, the movement in the demand for money is ambiguous. Note that the possibility of instability in this model does not depend on low elasticities of substitution between food and nonfood, but on the strength of substitution effects between assets in the portfolio.

Temporary price changes, however, are now much less likely to cause instability, because a temporary shift in the value of money or food will induce stabilising speculative portfolio substitution. For instance, a temporary fall in the price of food or a temporary increase in the CPI will induce movement into food or money respectively as the returns to the asset increase. This recalls Hicks' (1939) finding that the stability of temporary equilibrium depends on the elasticity of expectations. In practice, agents might be expected to regard movements in the relative price of food as temporary, resulting from supply shocks, but to regard increases in the CPI as permanent; certainly, the statistical persistence of nominal prices tends to be higher than that of relative prices. But if a food price increase is expected to persist into the next period, it has a similar effect to a permanent increase.

As before, it does not seem to be possible to rule out multiple rational expectations equilibria in this economy. Equilibria with a higher price level would also have a higher relative price of food; risks facing households would be higher, food stocks would be higher (hence aggregate food consumption lower) and social welfare lower. In contrast to others sources of 'flight from money' that have been considered in the literature, this arises not from a hyperinflation but because a reduction in liquidity induces flight into the safest asset, which is food.

It is worth noting, finally, that the presence of risk-neutral traders would tend to stabilise the system. Food would be stored only when the expected increase in its relative price offset the rate of physical deterioration. However, the presence of agents who behave as though they were risk-neutral is unlikely unless they have access to credit outside the system. The likely policy implication is that the availability of formal sector credit to agricultural traders can assist the stabilisation of food markets, providing potentially important indirect benefits to the poor. The functioning of financial markets may matter for famine even if the poor never themselves receive credit - just as, in the Keynesian case, a generous attitude to default by firms may alleviate the distress suffered by workers in a recession.

Welfare implications

It is useful to compare the various equilibria in this economy to the alternative possibilities. In comparison to the Arrow-Debreu economy, this economy will have lower social welfare and more unstable individual consumption. It will also have lower total consumption, because the holding of stocks by uninsured agents fails to reap the potential benefits of risk-sharing; as a result not only are risks higher but more food in aggregate is stocked, increasing losses due to deterioration. However, the economy will be somewhat more stable, and have higher social welfare, than the economy without money. If there are multiple equilibria, those with lower food prices, and those with lower levels of the CPI, in general have higher social welfare.

Interestingly, although increases in the price of food increase agents's risks and agents in the Arrow-Debreu economy face reduced risks, it does not follow that prices would be less volatile in the Arrow-Debreu economy. In the Arrow-Debreu case, because agents are insured, intra-period income effects are weak and therefore price volatility has an important role in producing the substitution effects which achieve equilibrium. Hence we cannot conclude that price volatility is a problem as such. The inefficiencies arise rather from the existence of liquidity constraints which are exacerbated by increases in the level, rather than the volatility, of food prices and the CPI.

7 Conclusions

As noted early in the paper, the absence of insurance markets makes it generally true that food price movements may have unpleasant welfare effects. The possibility of multiple equilibria, however, has not been previously raised in this form. I conclude by discussing three issues.

First, instability in the current model is not certain, and the likelihood of its occurring is reduced further if there is a positive supply response. What is generally true, however is that prices movements affects the asset demand for food and this is likely to make demand curves steeper than they would otherwise be. Where agents are liquidity-constrained, the extra price volatility has a welfare cost. This is not to say that food storage should be discouraged or that price volatility is necessarily bad; the no-storage case is likely (though not certain) to have lower social welfare than that with storage, and the Arrow-Debreu model might have even higher price volatility, but it would not matter because agents would be insured. It does, however, provide some basis of thinking that high volatility in food prices may be damaging, especially if there are other reasons (such as visible destitution) for thinking that agents are not fully insured.

Secondly, the empirical testing of these effects raises some problems. First, the slope of the demand curve may be quite different for price changes that are expected to be permanent and those that are expected to be temporary, but usually expectations are not observed. Secondly, in practice an increase in food prices will often accompany a collapse in income; only if income is well accounted for would it be possible to identify the perverse slope of demand. Thirdly, the proper interpretation of coefficients becomes difficult if the economy is sliding between equilibria. Fourthly, the demand curve defined here includes demand for stocks, but high-frequency and accurate data on aggregate household food stocks is rarely if ever available. Finally, if supply factors such as weather are used as an instrument then only temporary changes can be estimated, but in the presence of money it is permanent changes that are most likely to cause instability.

Finally, policy implications also require careful thought. The most fundamental point is negative; price changes during famine may reflect asset effects as well as scarcity: and a mechanism that has previously behaved well may become unstable during famine. A second set of issues relates to price interventions. In the models considered here, a reduction in the price of food is beneficial because it reduces the risks facing agents \and also reduces the variance of real income within the current period. But in practice, the insurance benefits of food price reductions may conflict with distributional objectives, because rural residents are chronically poorer than urban residents. The insurance benefits of reductions in the volatility of the food price are more robust, and these provide an argument for liberalising trade in food in economies which are subject to large supply shocks. Finally, the risks characteristic of these models can be addressed by policies to encourage the poor to broaden their portfolios of assets including the development of savings institutions and low inflation. The existence of insured and risk-neutral traders tends to stabilise the system; bank credit to the trading sector may be helpful here, as it is for the Keynesian case where the illiquidity of firms increases the risks which workers face. However, all such policy interventions need to take account of existing informal institutions which pool or reduce risk.

References

Alderman, H. and C.Paxson, (1992) "Do the poor insure ? a synthesis of the literature on risk and insurance in developing countries", Discussion Paper no.164, Research Program in Development Studies, Woodrow Wilson School of Public and International Affairs, Princeton University

Arrow, K. and F.Hahn (1971) General competitive analysis, North-Holland

Bardhan, K. (1969) "A note on the price-elasticity of demand for foodgrain in a peasant economy", Oxford Economic Papers Vol. 21, No.1, pp. 104-8

Deaton, A. (1989) "Saving in developing countries: theory and evidence", Proceedings of the World Bank Annual Conference on Development Economics, pp.61-96

Deaton, A. (1991) "Savings and liquidity constraints", Econometrica Vol. 59, No.5, pp.1221-48

Deaton, A. and J.Muellbauer (1980), Economics and consumer behaviour, Cambridge University Press

Devereux, S. (1993) Theories of famine, Harvester Wheatsheaf

Grandmont, J. (1988), ed., Temporary equilibrium: selected readings, Academic Press

Hicks, J. (1946) Value and capital, Clarendon Press

Hurwicz (1969) "On the concept and possibility of informational decentralization", American Economic Review Vol.63. No.2, pp.1-30

Keynes (1936) The general theory of employment, interest and money, Macmillan

Lardy, N. (1983), Agriculture in China's modern economic development, Cambridge University Press

Lipton, M. (1982) "Poverty, undernutrition and hunger". World Bank Staff Working Paper no.597

Lucas, R. (1978) "Asset prices in an exchange economy", Econometrica Vol.46 No.6 pp.1429-45

Lucas, R. (1981) Studies in business-cycle theory, Blackwell

Newbery, D. (1989a) "Missing markets: consequences and remedies", in F.Hahn, ed., "The economics of missing markets, games and information", Clarendon Press

Newbery, D. (1989b) "The theory of food price stabilisation", Economic Journal Vol.99 pp.1065-82

Ravallion, M. (1985a) "The performance of rice markets in Bangladesh during the 1974 famine", Economic Journal Vol. 95, No. 277, pp.15-29

Ravallion, M. (1985b) "The information efficiency of traders' price expectations in a Bangladesh rice market". Oxford Bulletin of Economics and Statistics, Vol. 47, No.2, pp.171-84

Ravallion, M. (1987) "Markets and famines", Clarendon Press

Stahl, D. (1987) "Temporary equilibrium with storable commodities", Journal of Economic Theory Vol.42, No.2, pp.262-74

Tirole, J. (1982) "On the possibility of speculation under rational expectations", Econometrica Vol.53, No. 6, pp.1499-1528

Tobin, J. (1980) Asset accumulation and economic activity, Blackwell

Appendix: Proof of Proposition One

The proposition to be proved states that **for a permanent change in price, starting from a constant-price steady state, if the utility function v(C) is characterised by linear marginal utility, constant absolute risk aversion, or constant relative risk aversion, then for agents with consumption and net food sales above a certain level**

$$\frac{dC_{it}}{dp_f} < Q_{it} \qquad \textbf{(59)}$$

The Euler equation takes the form:

$$v^{/}(C_{it}) = \rho\delta_f E_t v^{/}(C_{it+1}) \qquad \textbf{(60)}$$

Consider the following decomposition of the change in future consumption:

$$\frac{dC_{it+1}}{dp_f} = \frac{\delta C_{it+1}}{\delta z_{ift+1}}\frac{dz_{ift+1}}{dp_f} + \frac{\delta C_{t+1}}{\delta p_f}\Big|_{z_{ft+1}\ const} \qquad \textbf{(61)}$$

Totally differentiating (60) and substituting (61) in, we get

$$v^{//}(C_{it})\frac{dC_{it}}{dp_f} = \rho\delta_f Etv^{//}(C_{it+1})\ (\frac{\delta C_{it+1}}{\delta z_{ift+1}}\frac{dz_{ift+1}}{dp_f} + \frac{\delta C_{t+1}}{\delta p_f}\Big|_{z_{ft+1}\ const}) \qquad \textbf{(62)}$$

I now assume that in fact all the income generated is spent:

$$\frac{\delta C_{it}}{\delta p_f}\Big|_{z_{ift} const} = Q_{it}\ for\ all\ t \qquad \textbf{(63)}$$

This will imply, from the budget constraint, that

$$\frac{dz_{ift+1}}{dp_f} = 0 \qquad \textbf{(64)}$$

and hence, from (63),

$$\frac{dC_{it+1}}{dp_f} = Q_{it} \qquad \textbf{(65)}$$

Substituting back into (62), this implies

$$v^{//}(C_{it})Q_{it} = \rho\delta_f E_t v^{//}(C_{it+1})Q_{it+1} \qquad \textbf{(66)}$$

and expansion of the product gives

$$v^{//}(C_{it})Q_{it} = \rho\delta_f E_t v^{//}(C_{it+1})E_t Q_{it+1} + \rho\delta_f cov(v^{//}(C_{it+1}),Q_{it+1})) \qquad \textbf{(67)}$$

Consider now the forms of utility function specified in the proposition. Under linear marginal utility, (67) implies that

$$E_t Q_{it+1} > Q_{it} \qquad \textbf{(68)}$$

But it was shown in Section 2 that this cannot generally be true; above a certain level of Q_{it} the opposite inequality holds. As a result, above a certain level of income, the behaviour described in (63) would imply that

$$v^{//}(C_{it})Q_{it} < \rho\delta_f E_t v^{//}(C_{it+1})Q_{it+1} \quad \textbf{(69)}$$

violating the Euler equation.

Similarly, for constant absolute risk aversion, we have

$$\frac{v^{//}(C_{it})}{v^{/}(C_{it})} = k_a \quad \textbf{(70)}$$

and substituting this into (62) yields

$$Q_{it} = E_t\rho\delta_f Q_{it+1} + \rho\delta\frac{k_a}{u'(C_{it})}cov(v^{/}(C_{it+1}),Q_{it+1}) \quad \textbf{(71)}$$

Because the covariance is negative, as was shown in Section 2, (68) is established again and the unacceptable conclusion (69) is reached.

Finally, for constant relative risk aversion,

$$\frac{v^{//}(C_{it})C_{it}}{v^{/}(C_{it})} = k_r \quad \textbf{(72)}$$

and (67) now gives

$$Q_{it} = E_t\rho\delta_f Q_{it+1} + \rho\delta\frac{k_a}{v'(C_{it})}cov(v^{/}(C_{it+1}),Q_{it+1}/C_{it+1}) \quad \textbf{(73)}$$

and (68) and the unacceptable conclusion (69) again follow.

Examining (69), it can be seen that for, some agents, the behaviour assumed in (63) has caused $u'(C_{it})$ to fall further than $\rho\delta_f E_t u'(C_{it+1})$. To preserve the Euler equation, it will therefore be necessary that foodstocks increase; this will imply (59). This completes the proof.

Figure 1: demand for food, global stability of unique equilibrium

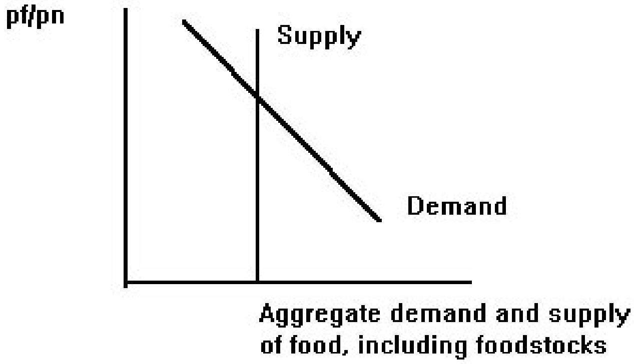

Figure 2: demand for food, multiple equilibria with global stability

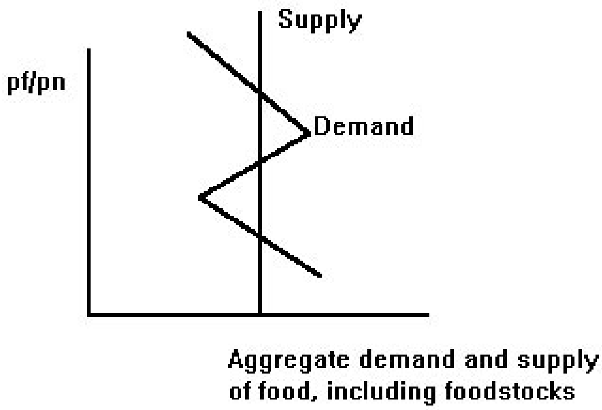

Figure 3: demand for food, multiple equilbria and no global stability

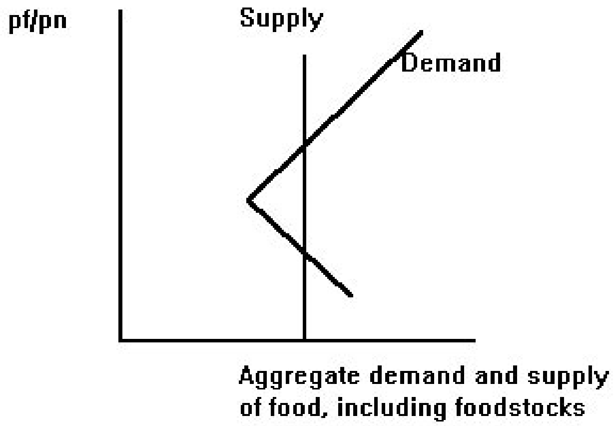

Figure 4: multiple steady states