AN OPTIMAL PATH TO EXTINCTION?

Poverty and Resource Degradation in the Open Agrarian Economy

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This paper constructs a model of the open agrarian economy in order to explore the tendency of many such economies to evolve along paths characterised by severe environmental degradation. It pays special attention to the importance of commodity prices and the transfer system in determining agricultural activity levels in ecologically delicate systems.

1. Introduction

This paper develops a theory of resource degradation and poverty in the agrarian economies that is independent of the Malthusian explanations common in much of the literature. The empirical problem at issue is a very general one. The environmental despoliation of the Sahel and the Horn of Africa, and the destitution of much of the population of these areas in the last two decades, are not unique. The combination of rural poverty and resource degradation has in fact become a problem of increasingly severe proportions in the agriculturally and pastorally based economies of Africa, Asia and Latin America. Despite its enormous welfare costs and the ex animo concern it generates, comparatively little has so far been done to explore the causes of the problem at a theoretical level. This paper offers a perspective on the link between resource degradation and poverty in open

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1See, for widely differing examples of works that assign final responsibility for environmental degradation to population expansion Eckholm (1976) and Ruddle and Manshard (1981). The arguments of this paper are consistent with population-induced changes in activity levels, but are concerned with a shorter time frame than is ordinarily assumed in population-driven models. They would also lend support to the claims of such as Kates, Johnson, and Haring (1977). that the relation between resource degradation and population expansion is non-monotonic. It is increasingly recognised that there may be other factors in resource degradation that are more important than population expansion, implying that the proximate causes of resource degradation overstocking and overcultivation bear no systematic relation to population increase (cf. Repetto and Holmes (1983) and Pearce (1987)). This paper investigates one set of such factors.
agrarian economies that take as its point of departure the exhaustible nature of the basic resource in agricultural or pastoral activities – land. The results of the paper spring both from the sensitivity of the environment to changes in the level of agricultural or pastoral activities (a physical problem) and from the intertemporal choices of agents operating near the minimum level of subsistence (an economic problem).

The focus of the paper is the open agrarian economy. Open agrarian economies differ from closed agrarian economies primarily in the scope for accommodating uncertainty offered by environmentally conservative production strategies. In open agrarian economies the prices of inputs and outputs are set in the world market, so the level of real income is determined by factors that lie outside the control of the agents of the economy. To be sure, income changes with the same climatic factors that influence all agrarian activity, but it is also susceptible to price fluctuations. Where agrarian incomes are such that there is little surplus to forego if the terms of trade turn against such economies, there may be few alternatives to increasing activity levels regardless of the environmental risks involved. Indeed, the interesting thing about open agrarian economies of the type described here, is that relative price shifts can lead to a positive feedback process in which increasing levels of activity lead directly to deepening poverty and resource degradation.

A concern with the potentially adverse effects of change in the economic and natural environments of open agrarian economies means that the paper addresses questions raised in several quite distinct areas of the literature. Some of these questions have been causing concern for a considerable period of time. Amongst these, the potentially adverse effects of trade between more and less developed economies that has attracted the persistent attention of trade and development theorists alike – the prospect of immiserizing growth – can be traced back to the work of Friedrich List in 1837. This paper offers explanations for such potentially adverse effects that have parallels in both the elasticity arguments of, for example, Bhagwati (1958, 1968) and the specialisation loss arguments of, for example, Metcalfe and Steedman (1979). Where the arguments of this paper diverge from those offered elsewhere is in the suggested causes of the adverse effects of trade. It is the exigencies of poverty that raise the prospect of immiserizing growth.

Because I am concerned with the time-behaviour of open agrarian economies, the paper also touches on a related literature on the long-run dynamics of agrarian economies stimulated by Boserup’s anti-Malthusian models (1965, 1981). Darity (1980) and Pryor and Maurer (1981) have both developed formal models of the intensification of subsistence production within a defined technological horizon in terms of an exogenously determined population growth function; Darity for an open economy, Pryor and Maurer for a closed economy. The model developed in this paper is similarly
concerned with the intensification of production within a defined technological horizon, and this is similarly taken to be a response to exogenously determined stimuli. It nevertheless differs from the Darity and Pryor-Maurer models in certain important respects. Most obviously, it is not population growth, but the effects of change in the world economy on levels of agrarian poverty that drive the intensification of production. In addition, the period of interest is not the centuries envisaged by Boserup, Darity, or Pryor and Maurer. It is the span of a generation. I am interested in changes occurring within the rhythms of population adjustment. Agrarian producers at the minimum level of subsistence faced with exogenous price shocks cannot wait to respond by natural demographic adjustments. I am, therefore, interested in a more urgent problem altogether.

Partly because of this difference in time perspective, the model discussed in this paper is also more directly influenced by the exhaustible nature of the natural resources exploited by rural producers. The cost of increased intensity is not just diminishing returns, it is potentially the complete collapse of the economic system. The exhaustibility of arable or pastoral resources is not, of course, directly analogous to the exhaustibility of, say, a mineral deposit. What both have in common, though, is the irrevocability or irreversibility of the changes involved. Arable or pastoral land is only renewable if agrarian activity does not involve irreversible change that makes that land useless under the technology applied. If it does involve such change it is to all intents and purposes exhaustible. The paper accordingly addresses a set of very old questions about the nature of environmental strategies in the face of exhaustible resources and technological inflexibility, posed both in economics and anthropology for a fuller discussion of which see Perrings (1987).

This points toward one final set of questions addressed in this paper concerning the connection between poverty and resource degradation, and that is the set of questions raised in Sen's (1981) seminal inquiry into the proximate causes of famine. This paper is motivated, above all, by the experience of the open agrarian economies that dominate rural sub-Saharan Africa. The famines that have decimated areas of Ethiopia, the Sahel and currently Mozambique, are only the most obvious signs of widespread resource degradation and poverty in these economies. The failure of trade,

\[^{2}\]Dryland ecosystems tend to be particularly vulnerable to increasing resource use. Vegetational cover tends to be sparse, and soils tend to be poor in organic matter and nutrients. Devegetation can result in damage from which recovery, in the sense of a return to existing conditions, may never occur. More particularly, greater exposure of the surface of the soil results in lower water retention, encouraging sheet and gully erosion, and reducing the productivity of economically useful plants [see Ruddle and Manshard (1981)]. It is also argued that reduction in surface vegetation may have climatic effects. It may increase surface albedo (reflectivity of solar radiation), and this may cause the air to lose heat radiatively, and so to descend, losing relative humidity in the process [Charney (1975), Hare (1977)].
direct, and transfer entitlements after years of 'rural development' implies that we are somehow misreading the probable effects of the commercialisation of agrarian economies. This paper suggests that the impact of any change in the economic environment of an open agrarian economy will vary with both the level of activity (the intensity of resource use within the existing technological horizon), and with the sensitivity of the natural environment to change in that level. Because perverse effects are not only possible but inevitable in certain cases, it may be useful to have a sense of the combination of circumstances that make this so.\(^3\)

2. Characterising the open agrarian economy

The differentia specifica of agrarian economies everywhere are a heavy reliance on agricultural or pastoral activities, and the use of a typically rudimentary technology that is constant over extended periods. Fei and Ranis have described such economies as 'essentially stagnant with nature and population vying for supremacy over long periods of recorded history. Moreover ... the prognosis for the future is likely to be "more of the same"' (1978, p. 2). Schultz (1964) saw this as a 'particular type of economic equilibrium' in which the state of the arts (production functions) and preferences (utility functions) were both constant, in which the marginal physical product of all resources employed was zero, and net savings were close to zero. The last two properties were linked; the incentive to save being weak because of the low marginal physical product of 'capital'. The longevity of the technology employed in agrarian economies was taken by Schultz to imply that the particular type of economic equilibrium he describes was, in fact, stable.

This agrees with the more formal model of the closed agrarian economy constructed by Leibenstein (1957) which generated what the author called a quasi-stable equilibrium, or a stable equilibrium conditional on the economy concerned being insulated from external influences. Later attempts to model the dynamic properties of agrarian economies have been less in accord. Pryor and Maurer, for example, observe that of sixty such economies researched by one of the authors, all 'seemed either to be at, or moving towards, a static equilibrium' (1982, p. 326), making it slightly ironic that the closed agrarian economy models developed by the authors converged to positive growth paths in most cases, even though they recognised that under their own assumptions there had to be 'long-run limits' to the growth of the economy (1982, p. 346). By contrast, the open economy model constructed

\(^3\)The paper does not, therefore, address the link between resource degradation and technological change. It is worth noting, however, that many of the most commonly cited instances of technological change - the introduction of deep wells, for example - may be interpreted as the intensification of activity within a given technology.
by Darity (1980), generates a highly unstable equilibrium – a knife edge – divergence from which necessarily leads either to the collapse or to the sustained growth of the system. There is at least a superficial similarity between the approaches of Darity and Leibenstein, in that the opening of the ‘backward’ economies described by Leibenstein was argued to create at least the possibility of similarly sustained disequilibrium growth. The two did, however, have different historical circumstances in mind when discussing the opening of traditional agrarian economies – particularly in Africa. For Darity it was the trade in slaves not goods that was important.

The anthropological evidence suggests that the apparent stability of closed agrarian economies was the product of a range of institutional control mechanisms designed to guarantee the economy in the face of an uncertain environment [see Herskovits (1940), Nash (1967) and Sahlins (1974)]. Using such anthropological evidence I have argued elsewhere [Perrings (1985)] that the dominant feature of agrarian economies is the existence of institutions to limit the level of capacity utilisation to environmentally sustainable levels. There is no reason to believe, however, that such economies were economically stable. Since real income and savings are both positively correlated with agriculturally favourable environmental conditions (rainfall etc.), the unregulated closed agrarian economy should be prone to exactly the same climatically determined overgrazing and overcultivation that has been argued as a cause of resource degradation in the Sahel. The existence of institutions to restrict investment to sustainable levels appears to have been a crucial factor in the longevity of economically unstable or only locally stable closed agrarian economies.

The opening of the agrarian economies of Africa both through the slave trade and their incorporation in world product markets has changed their characteristics in very important ways. Since certain input and output prices are set in world markets the link between real income, savings, and local environmental conditions has been partly severed. More particularly, the role of traditional institutions in regulating capacity utilisation has been substantially weakened, with implications both for the incentive effects of traditional communal or common property, and for the way that uncertainty is accommodated. There are now two sources of uncertainty – the environment and the world market – and the behaviour of agrarian producers is very much a function of the methods chosen to minimise risk in both areas.

In all open agrarian economies, producer strategies for minimising risk hinge on decisions in two areas: the traditional choice as to the optimal level of activity; and a new choice between production for either direct consumption or for the market [Livingstone (1981)]. The important point here is that neither the market risk nor the direct consumption risk of harvest failure are insurable except through the decisions made by agrarian producers in these two areas. Accordingly, since producers near the minimum subsistence level
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simply cannot take a loss below subsistence, they tend to adopt what Lipton (1968) has called 'survival algorithms': environmentally conservative practices characterised by the selection of low value but robust crops or livestock suitable for both market production and direct consumption. They tend to avoid high (market) value but environmentally susceptible crops or livestock that are not directly consumable if need be [cf. also Yamey (1964)]. The risk minimising strategies of producers in the open agrarian economies accordingly bias production and consumption decisions in favour of tried practices and traditional products, and against technological innovation. Opening the agrarian economy does not therefore necessarily lead to the adoption of innovation practices, particularly where technological change is itself a source of risk [see Schultz (1964)]. The costs of such technological conservatism, in terms of the specialisation losses of trade, are implicitly accepted as part of the premium to be paid for the risk of participating in the world market.

A very similar set of considerations inform the savings behaviour of agrarian producers. Savings in the open agrarian economy may notionally be made in the form of either financial or real assets; money, bank deposits and the like, or grain and livestock. In fact the possibility for saving in financial assets tends to be limited by the availability of financial institutions, though the absence of such institutions may also be a consequence of the fact that the safety oriented survival algorithms employed favour saving in real assets. Saving in real assets provides both a means of direct consumption in the case of drought (insurance against direct entitlement failure) and a degree of protection against the volatility of product prices (insurance against trade entitlement failure). An important implication of this is that savings and investment decisions tend to be taken by the same agents. Real savings realised by 'household abstention' imply direct investment by the household head [Firth (1964)]. Capital in the open agrarian economy is not freely mobile.

Like all other dynamic economies, the open agrarian economy is driven by savings, but it is savings out of the discretionary income of people living close to the poverty line and poverty turns out to have crucially important effects. Poverty, in this context, is 'subjective' in the sense that it is defined by the agents' own assessment of need [see Drewnowski (1977)] (though few would deny that the subjective poverty of refugees in Mozambique or the Sudan involves real deprivation). For present purposes poverty may be said to exist wherever there is dissaving to maintain consumption. The degradation of natural resources – whether the dev egetation of woodlands, the exhaustion of soil nutrients, the deplenishment of aquifers, or the starvation

Recently the savings of agrarian producers in terms of real assets has been interpreted by Ravallion as speculative hoarding (1987), but this misses the insurance role of real savings in economies where most producers are close to the minimum level of subsistence.
of livestock – represents dissaving of the most important assets of the agrarian economy, and there are few better indicators of the extent of rural poverty.

A final characteristic of agrarian economies worth noting relates to the intra household distribution of income and division of labour. While there certainly exists a division of labor based on both age and gender, none is exempt from labour save the very old and the very young. All members are therefore assumed to belong to the household workforce. For convenience it is assumed that all have an equal claim to household income. These various characteristics are now summarised in the formal model of the open agrarian economy.

The income generated by agricultural or pastoral activity under the state of nature prevailing in the kth period of the history of the economy is defined by

$$Y(k) = Q(k)[b[Q(k)]P(k + 1) - aP(k)],$$  \hspace{1cm} (1)

where $Y(k)$ denotes income; $Q(k)$ denotes the level of activity, or the level of intensity of resource use; $b[Q(k)]$ denotes a unit activity level output coefficient as a function $Q(k)$; $a$ denotes a constant unit activity level input coefficient; and $P(k + 1)$, $P(k)$ denote ‘world’ prices of agrarian outputs and inputs respectively. All except the input coefficient, $a$, are variable over time. Time is treated discretely since this seems to be the most natural way of dealing with production that is seasonal in nature. Income is distributed equally to all members of the agrarian labour force, which is assumed to be of constant size in the period of interest (the span of a generation). Hence

$$Y(k) = NW(k),$$  \hspace{1cm} (2)

where $N$ denotes the agrarian labour force, and $w(k)$ denotes the income of each member of the labour force. Since the intensity of labour varies with the level of activity we have also

$$Y(k) = Q(k)n(k)w(k),$$  \hspace{1cm} (3)

where $n(k)$ denotes the intensity of labour. The higher the level of activity the greater the intensity of agrarian labour.

Production in the agrarian economy may thus be characterised by a function relating output, $Q(k)b[Q(k)]$, to labour, $Q(k)n(k)$, and material inputs, $Q(k)a$. Land is assumed to be in fixed supply and only enters the production function implicitly, via its effect on the productivity of fixed quantities of labour and material inputs used at differing levels of intensity. This enables us to capture the role of a factor of production that is not
traded in the ordinary sense. The technology, in other words, reflects the fact that labour and material inputs are combined with a potentially exhaustible resource, land.

The effects of pressure on land is captured in the value of the output coefficient under different activity levels. This is taken to exhibit first increasing and then diminishing returns. Omitting the time index for the moment, the first derivatives of \( b(Q) \) are positive for all \( Q \) up to some value \( Q_{\text{bmax}} \) (defined later) and are negative thereafter; the second derivatives are positive for all \( Q \) up to some value \( Q < Q_{\text{bmax}} \), and are negative thereafter for most \( Q \) of interest. That is:

\[
\begin{align*}
  b'(Q) &> 0 \quad \text{for all } Q \leq Q_{\text{bmax}}, \\
  &< 0 \quad \text{for all } Q > Q_{\text{bmax}}, \\
  b''(Q) &> 0 \quad \text{for all } Q < Q < Q_{\text{bmax}}, \\
  &< 0 \quad \text{for most } Q > Q.
\end{align*}
\]

Notice that this precludes the parabolic function normally assumed in exhaustible resource problems, since it insists that there are increasing returns to scale at low levels of intensity of resource use. In general, therefore, we would expect the graph of the function to be of the form shown in fig. 1. For concreteness, however, I have assumed the function to be of a very specific, symmetrical, form:

\[
b = b_{\text{max}} \exp\left[-\frac{1}{2}(Q - Q_{\text{bmax}})^2\right], \tag{4}
\]

where \( b_{\text{max}} \) denotes the maximum unit activity level output coefficient; \( Q_{\text{bmax}} \)
denotes the activity level at which \( b \) attains a maximum. This function has all the required properties described above. Its graph is of the form shown in fig. 2.

Although, as we have seen, changes in the level of intensity are not driven by population in the time scale of interest in this paper, they do have similar implications for the time path of the system. Since land is regarded as an exhaustible resource there are very clear and well-defined limits to the intensity at which it can be exploited under a given technology, and a given state of nature. To reflect the effects of change in the state of nature of the value of \( b(Q) \) eq. (4) will be written in the time indexed form:

\[
b(k) = b_{\text{max}}(k) \exp[-1/2(Q(k) - Q_{\text{max}})^2].
\]  

(5)

To explore the dynamics of the open agrarian economy we need to specify the savings behaviour of agrarian producers. Total savings are defined by

\[
S(k) = s(k) Y(k),
\]  

(6)

where \( s(k) \) denotes the agrarian producers propensity to save in period \( k \). It may be positive, negative or zero. As indicated earlier, savings are determined by the relation between actual income and the perceived minimum subsistence needs of agrarian producers. This may be thought of as the poverty point, and is denoted \( w \). The relation between savings and poverty is then described by

\[
s(k) = \sigma [Y(k) - wN]/Y(k),
\]  

(7)
where \( \sigma \) is a positive constant indicating the fixed proportion of discretionary income saved. The general propensity to save accordingly varies with the amount of income earned relative to the (subjective) poverty point. In all periods,
\[
\omega \leq [1 - s(k)]w(k). \tag{8}
\]
Since investment in period \( k + 1 \) is simply
\[
I(k + 1) = Q(k + 1) aP(k + 1), \tag{9}
\]
the savings-investment identity takes the form
\[
Q(K + 1)aP(k + 1) = s(k)Q(k)n(k)w(k). \tag{10}
\]
Thus, if world prices are stable, the system is driven by the interaction of two variables: the propensity to save, and the productivity of complementary factors at the prevailing level of intensity of resource use. These two variables are not independent. More particularly, the propensity to save will rise (fall) with an increase in the level of intensity of resource use for all intensity levels less than (greater than) the maximum income level. To see this notice that the maximum income level of agricultural activity, found by setting the derivative of \( Y(k) \) with respect to \( Q(k) \) equal to zero, is given by
\[
Q_{\text{max}}(k) = \frac{C}{\sigma} \left( k + u_0 \right) W'(W + Q_{\text{max}}(k)), \tag{11}
\]
where \( V(k) = Q(k) b(k) P(k + 1) \) denotes the value of agrarian output. Taking the derivative of \( s(k) \) with respect to \( Q(k) \) in (7),
\[
\frac{ds(k)}{dQ(k)} = \frac{\sigma - s(k)}{y(k)} [n(k)w(k) - [Q(k) - Q_{\text{max}}(k)]V(k)], \tag{12}
\]
it follows immediately from (11) that this will be negative for all \( Q(k) > Q_{\text{max}}(k) \), and positive for all \( Q(k) < Q_{\text{max}}(k) \). As average income changes with the level of activity so too does discretionary income, and with it the propensity to save.

This completes the description of the formal structure of the open agrarian economy model. As with any model developed at a high level of abstraction from the reality it is intended to explain, it misses much of the richness of the social and political fabric within which agrarian producers make their decisions. It does, however, capture what seem to be the characteristics of agrarian economies most important to an understanding of their behaviour.
over time: the limited availability of grazing or arable land; the inflexibility of aggregate labour supply but the variability of the intensity of effort, the dependence on external markets for both inputs and outputs; the tendency to save real rather than financial assets (both output and land fertility) and the exhaustible nature of the principal resource. We can now consider the dynamics of the model.

3. The dynamics of the open agrarian economy model

A time path for resource use in an open agrarian economy with the above characteristics may be obtained from the phase line generated by the following non-linear first-order difference equation taken from the saving–investment identity (10):

\[ Q(k+1) = \frac{s(k)}{aP(k+1)}Q(k)[b(k)P(k+1) - aP(k)]. \] (13)

The level of activity in period \( k + 1 \) varies with three things: the propensity to save and the intensity of resource exploitation in period \( k \) (as we have already seen) and the change in world prices between periods \( k \) and \( k + 1 \). Taking the derivative of \( Q(k+1) \) with respect to \( Q(k) \) see the former we get

\[ \frac{dQ(k+1)}{dQ(k)} = \frac{\sigma}{aP(k+1)}[n(k)w(k) - [Q(k) - Q_{b_{\text{max}}(k)}]V(k)]. \] (14)

Once again, it follows immediately that the slope of the phase line deriving from (13) will be positive or negative as the level of agricultural activity is less than or greater than the maximum income level of intensity. The impact of prices is more easily seen if (14) is written in the form

\[ \frac{dQ(k+1)}{dQ(k)} = \sigma[(b(k)/a)[1 - [Q(k) - Q_{b_{\text{max}}(k)}]] - P(k)/P(k+1)]. \] (15)

Other things being equal, rising world prices will cause the level of activity to change more sharply. Falling world prices will have the opposite effect. Assuming constant world prices and positive savings, the phase line defining the time path of the system is of the general form described in fig. 3. The line \( Q(k+1) = Q(k) \), a 45° ray from the origin, indicates all points at which activity levels are constant. The phase line defined by the graph of \( Q(k+1) = s(k)Q(k)n(k)w(k)/aP(k+1) \) indicates the forward difference asso-
associated with each value of \( Q(k) \). Iterative calculation of that difference from the phase line enables us to construct a time path for the system.

In the discussion of the global and local stability of the system that follows, five values of \( Q(k) \) are of interest, two of which have already been defined. \( Q_{\text{ymax}}(k) \) is the maximum income level of activity. At that point the phase line has a slope of zero. \( Q_{\text{bmax}}(k) \) is the maximum productivity level of activity. At that point the phase line has a slope of \( s(k) n(k) w(k)/aP(k+1) \).

Two other values of \( Q(k) \) of interest lie at the intersection of the phase line with the \( Q(k+1) = Q(k) \) locus. These define the steady state equilibria of the system: that is, the levels of activity at which there is no impetus to change. Since \( Q_{\text{ymax}}(k) \) indicates a level of activity associated with higher average productivity than \( Q_{\text{emin}}(k) \), it will be referred to as the maximum income equilibrium activity level. \( Q_{\text{emin}}(k) \) will be referred to as the minimum income equilibrium level. Notice that the latter also denotes the minimum sustainable level of activity, in the sense that any level of activity below \( Q_{\text{emin}}(k) \) will lead to the collapse of the system. \( Q_{\text{max}}(k) \) denotes the maximum sustainable level of activity in the sense that any level of activity above \( Q_{\text{max}}(k) \) will similarly lead to the collapse of the system.

3.1. Global stability

The open agrarian economy may be said to be globally stable at a particular state of nature if the maximum attainable level of activity \( Q_{\text{ymax}}(k+1) \) is no greater than the maximum sustainable level of activity...
$Q_{\max}(k)$, and to be globally unstable if this is not true. This is shown heuristically in figs. 4 and 5. Fig. 4 illustrates the globally stable case where $Q_{y_{\max}}(k+1) < Q_{\max}(k)$. It can be seen that the forward difference corresponding to every feasible activity level is sustainable, where an activity level, $Q(k)$ is defined to be feasible if $Q_{\epsilon_{\min}}(k) \leq Q(k) \leq Q_{\max}(k)$. A time path constructed for one such feasible initial level of activity, $Q(k=0)$ is shown. Fig. 5 illustrates the opposite case, where $Q_{y_{\max}}(k+1) > Q_{\max}(k)$. It can be seen that there exists a range of feasible activity levels, $Q_{y_{\max}}(k+1) \pm \epsilon$, for which the corresponding forward difference is not sustainable. Assuming an initial
activity level $Q(k=0)$ on the edge of the feasible range, fig. 5 shows that the time path of the system will take it into the range of unsustainable activity levels, leading to a general collapse. The system is globally unstable.

The intuition behind this should be clear. An unstable economy is one in which certain feasible levels of activity lead to unsustainable activity levels in the future. Economically, it is the rate of potential savings associated with these levels of activity that creates the problem. More particularly, the open agrarian economy will be globally stable at a particular state of nature and for a constant set of world prices if the maximum potential rate of savings per unit activity level is no greater than the ratio of maximum sustainable to maximum attainable levels of activity, and will be globally unstable otherwise.

The maximum potential rate of savings per unit activity level may be defined by $s_{y\text{max}}(k)[(b_{y\text{max}}(k)/a)-1]$, where $s_{y\text{max}}(k)$ and $b_{y\text{max}}(k)$ are the savings propensities and output coefficients corresponding to the maximum income activity level, $Q_{y\text{max}}(k)$. The system will therefore be globally stable if

$$s_{y\text{max}}(k)[(b_{y\text{max}}(k)/a)-1] \leq Q_{\text{max}}(k)/Q_{y\text{max}}(k)$$

for all $k \geq 0$, and will be globally unstable if

$$s_{y\text{max}}(k)[(b_{y\text{max}}(k)/a)-1] > Q_{\text{max}}(k)/Q_{y\text{max}}(k).$$

Internally generated savings that cannot flow out of the system, and that lead to unsustainable levels of activity may cause the collapse of the system.\(^5\)

Notice that global stability in the sense of this paper does not necessarily imply that the system will converge to a steady equilibrium from any feasible initial activity level. The system may be convergent or it may be oscillatory. Global stability implies only that for a constant state of nature and world prices, a feasible initial level of activity will correspond to a time path in which activity levels in each period are both feasible and sustainable.

### 3.2. Local stability

The local stability of the steady state equilibria of the system depends on the absolute value of slope of the phase line at the points $Q_{\text{emin}}(k)$ and $Q_{\text{emax}}(k)$. If this is less than unity, the equilibria are locally stable; if greater than unity they are locally unstable. If the steady state equilibria are locally

\(^5\)Since it is assumed that world prices are constant, implying that $P(k) = P(k+1)$ for all $k \geq 0$, (16a) may be written in the form $Q_{\text{max}}(k) \geq Q_{y\text{max}}(k)[s_{y\text{max}}(k)/aP(k+1)][b_{y\text{max}}(k)P(k+1) - aP(k)]$ and since the right-hand side of this equation is just $Q_{y\text{max}}(k+1)$, the maximum attainable level of activity, the proposition merely restates the conditions for the global stability of the system.
stable the time path of the system will converge to the equilibrium point for any initial activity level in the neighbourhood of that point. If locally unstable the time path of the system will diverge from the equilibrium point for any initial activity level in the neighbourhood of that point. Fig. 4 illustrates the case of a system that is both globally stable, and locally stable at $Q_{e_{\text{max}}}(k)$. It is locally unstable at $Q_{e_{\text{min}}}(k)$. Figs. 6 and 7 illustrate two other possible cases. In fig. 6 the system is globally stable, but locally unstable at both the steady state equilibria $Q_{e_{\text{max}}}(k)$ and $Q_{e_{\text{min}}}(k)$. Small upward perturbations at $Q_{e_{\text{mid}}}(k)$ and small perturbations in either direction at $Q_{e_{\text{max}}}(k)$ will lead to a sequence of irregular undamped oscillations that take activity anywhere over the range of feasible activity levels. Fig. 7 illustrates the case of a system that is locally stable at $Q_{e_{\text{max}}}(k)$ but is globally

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1. Initial activity level outside the locally stable ranges $[Q]_{\text{sm}}(k)$ and $[Q]_{\text{sm}}(k)$.  
2. Initial activity level inside the locally stable ranges $[Q]_{\text{sm}}(k)$ and $[Q]_{\text{sm}}(k)$.  

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Fig. 6

Fig. 7
unstable. In this case small perturbations about $Q_{\text{emax}}(k)$ within the range $\{Q\}_{\text{max}}(k)$, or within the range $\{Q\}_{\text{min}}(k)$, will lead to the reconvergence of the system. Any other level of activity will lead to the collapse of the system.

Time paths for each of these cases are illustrated in fig. 8. The nature of the time path in all cases depends on the technological parameters of the system, and the saving behaviour associated with any given poverty point. Phase lines reflecting the fact that productivity and savings rates are little affected by the level of activity (a broad bell shape) are less likely to be associated with global instability than those reflecting the fact that small changes in the level of activity have significant effects on productivity and savings (a narrow bell shape). The latter indicate that diminishing returns at the intensive margin are important. The former indicate that they are not. Put another way, the more delicate is the ecological balance, the higher the probability that the system will be unstable, or at least unstable outside of a narrow range of activity levels. Many of the economies most affected by resource degradation would seem to be of this type.

4. Determinants of the level of activity

Consider, now, the potential for producers who are implementing quite rational security oriented 'survival algorithms' in globally unstable systems to
adopt programmes of activity that may lead to the degradation and possible collapse of the resource base of the economy. We may take the closed economy first. It was argued in section 2 that anthropological evidence suggests producers in closed agrarian economies sought to regulate the level of capacity utilisation to environmentally sustainable levels. This tendency to operate at an environmentally sustainable subsistence level which yet left considerable spare capacity suggests that such economies were institutionally held at or (proximately) above a point such as $Q_{e\min}(k)$, the minimum income steady state equilibrium. Such a position would ensure that even substantial fluctuations in the environment might be accommodated without risk of nearing the upper limits of sustainable activity. It would, coincidentally, also ensure that the increasing returns to scale available in the system were just exhausted. The longevity of such systems might then be attributed to the effectiveness of a set of social institutions designed to dispose of surpluses in an environmentally benign way. These institutions might reasonably be thought of as approximating a homeostatic control mechanism.\footnote{See Perrings (1987) for a more detailed discussion of the potential for homeostatic control in an evolutionary system.}

This interpretation would seem to be consistent with at least one other recent model of the agrarian economy. Although the construction of the Darity (1980) model is somewhat different from the model discussed in this paper, the knife edge equilibrium described by Darity is analogous to the point $Q_{e\min}(k)$ in all the cases discussed here. The use of a homeostatic control mechanism to minimise fluctuations about this equilibrium value might explain the paradox of an apparent tendency to static equilibrium in closed agrarian economies, when those economies had the potential for at least limited growth through the intensification of resource use. That the potential for growth should be limited follows from the assumption of fixed availability of land. Of course, neither Darity nor others who have developed formal anti-Malthusian models of the agrarian economy have considered what happens when the limits of intensification are reached. That, after all, is the Malthusian end of the problem.

Without stepping outside the bounds of the closed agrarian economy, it is apparent that under such a strategy any change in the natural environment, or any weakening of the strict regulation of the level of activity will force the system away from the steady state. If the system is globally stable an increase in activity levels will lead either to undamped oscillation (if it is locally unstable) or to convergence to the maximum income steady state equilibrium, $Q_{e\max}$. If the system is not only locally, but globally unstable, then the results may be collective disaster. Consider the state of nature first. It should be intuitively clear that a change in environmental conditions would be sufficient to dislodge an uncontrolled economy from an unstable steady state.
equilibrium. For example, drought lowers both the mean level of productivity, and increases the sensitivity of productivity to changes in activity levels. It thus changes the shape of the function (5). Hence a level of activity consistent with the steady state under historic environmental conditions will no longer be consistent with the steady state under the new environmental conditions. If changes in the state of nature are not adjusted to, or adjusted only with a significant lag, an apparently stable time path can very rapidly develop alarming instabilities. Where expectations are adaptive, as has been argued to be the case in agrarian economies [cf. Lipton (1968)] this indicates a problem in the speed of adjustment. Hare, for example, has argued that part of the physical problem in the Sahel may be attributed to the slow rate of adjustment to changes in environmental conditions. He claims that pastoralists have tended to build up herds in wet years, but have failed to reduce those herds during times of drought. This has led to additional pressure on drought stressed pastures and, after successive dry years, the result has been all the usual symptoms of the degradation of grazing land. Agriculturists, similarly, have extended the area of cultivation in wet years but have failed to contract that area in dry years, with similar results [Hare (1977); see also Konczacki (1978) and Ruddle and Manshard (1981)].

What is missed in such accounts is that stocking and cultivation decisions take place in circumstances where saving has an important insurance function, and where the opening of the economy has weakened many of the traditional controls over capacity utilization. In such circumstances over-stocking in particular makes perfect sense. As Sen has argued, it is entirely rational for individuals to overstock in times of drought for insurance purposes whenever grazing land has at least aspects of open access common property (res. nullius) [(1981, p. 110); see also the contributions in Ghai and Radwan (1983)]. Even without the common property problem, though, there is an incentive to hold on to stock in times of drought. As we have already seen, the closer to poverty agrarian producers are, the higher the insurance premium against starvation will be. The result is, as Lipton puts it 'increasingly desperate insurance measures, rather than more accurate allocation procedures' (1968).

Although failure to adopt to the natural environment may cause instability in the agrarian economy, so too may failure to adapt to the economic environment. The opening of the agrarian economies has typically thrust them into an economic environment which is highly uncertain, and in which they are at an enormous informational disadvantage. The result is that they are uniformly maladapted. It has long been recognised that in any move from autarky to trade there are losers and gainers, and there is no reason why the gains and losses from trade should be shared in any particular way. It is quite possible that the opening of a given economy will make all the agents of that economy worse off than under autarky. What is important
from the perspective of the open agrarian economies is that the welfare effects of trade depend on two effects: the exchange effect (the impact of change in relative prices on consumption) and the specialisation effect (the impact of a change in relative prices on the structure of production and choice of technique). Unlike the exchange effects of trade which are generally assumed to be positive, the specialisation effects may be positive or negative. More particularly, the specialisation effects may be positive only if there exists a choice of technique. Where the specialisation losses outweigh the exchange gains, it is possible that income will be less under trade than under autarky [cf. Metcalfe and Steedman (1979)]. Given the risk minimising strategies of agrarian economies it is not at all clear that the exchange effects of trade will be positive, and it is almost certain that the specialisation effects will be negative. It has already been remarked that the main evidence of the risk aversion of agrarian producers in the face of considerable climatic and market uncertainty is their commitment to tried practices. It is exactly this which makes them susceptible to specialisation losses, since it prevents them from producing efficiently under post-trade relative prices.

The result is that the commercialisation of agriculture has made the open agrarian economies of sub-Saharan Africa, in particular, more rather than less vulnerable to the exigencies of poverty. Environmental uncertainty has been augmented by market uncertainty. Exchange rate and price fluctuations are, potentially, at least, just as damaging as rainfall fluctuations. Indeed, Sen's whole thesis rests on the proposition that it is failure of trade entitlements (a market phenomenon) and not direct entitlements (food availability decline) that best explains many of the recent famines in Africa. Extreme poverty has occurred without any change in the aggregate output of food.

Famine due to the collapse of trade entitlements is bad enough. What is worse is that a failure of trade entitlements have highly damaging future effects on the physical system which threaten to make poverty not occasional but endemic. More particularly, where poverty due to unfavourable price movements raises the level of activity, it may lead to damped or persistent oscillations if the economy is globally stable, but to total collapse if the economy is globally unstable. In other words, a failure of trade entitlements in the present may cause a permanent decline of food availability in the future. To see this, let us relax the assumption that savings are positive and consider the output and input price elasticities of agrarian activity. From eqs. (7) and (13) the output price elasticity of agrarian activity is simply

$$\frac{dQ(k+1)}{dP(k+1)} \cdot \frac{P(k+1)}{Q(k+1)} = \frac{\sigma V(k)}{s(k)Y(k)} - 1,$$

(17)

while the input price elasticity is
\[
\frac{dQ(k+1)}{dP(k)} \cdot \frac{P(k)}{Q(k+1)} = -\frac{\sigma\lambda(k)}{s(k)Y(k)}.
\]

If \(s(k) > 0\) the algebraic signs of these elasticities are unambiguous and as expected: (17) is positive, and (18) is negative. Notice, though, that both turn on the savings propensity, \(s(k)\), and this is a function of the level of subjective poverty (the difference between actual income \(Y(k)\) and the minimum subsistence income \(wN\). From (7) \(s(k)\) is positive or negative as \(Y(k)\) is greater than or less than \(wN\). The response of producers to changes in either input or output prices will therefore be perverse wherever they are in subjective poverty, implying dissaving to maintain consumption levels. More prosaically, when the need to stave off starvation governs all current production decisions it may be expected that people will ignore the future consequences of these decisions. If the price of output falls, or the price of inputs rises, and if this drives agrarian income below the poverty line (the minimum subjective subsistence level) agricultural activity will rise to compensate – even if the future costs approach infinity. Poverty may be expected to drive up their rate of time preference to the point where all that matters is consumption today.

The future of agrarian producers in these circumstances depends on whether or not the system is globally stable. If it is globally unstable the level of activity will be driven to the point where the environment is irreversibly damaged, in terms of its usefulness under the existing technology. This does not imply an irrational approach on the part of agrarian producers to intertemporal choice. It merely implies that intertemporal decision-making is dominated by the exigencies of the present. Defining a discounted consumption stream over \(T\) periods to be

\[
P\{Y(k)\}_T = \sum_{k=0}^{T} [1 - s(k)Y(k)] [1 + d]^k, \quad k = 0, \ldots, T.
\]

If \([1 - s(0)Y(0)] = wN(\sigma = 1)\) with \(s(0) < 0\), and \(Y(0)\) set residually, it implies that the endogenously determined discount rate (or minimum rate of time preference), \(d\), will be found in the solution to

\[
s(0)Y(0) = Y(0) + \sum_{k=1}^{T} [1 - s(k)] Y(k)[1 + d]^k, \quad k = 1, \ldots, T.
\]

d accordingly denotes a poverty-determined rate of discount. Even if the
choice of \(Q(0)\) does drive the economy on to an unstable time path, the future costs of present decisions will necessarily be fully discounted. It will always be preferable to starve tomorrow rather than today. Consequently, irrespective of the 'rationality' of expectations, rational intertemporal choice that raises current output at the cost of future output may lead the agents of globally unstable open agrarian economies to collapse.

If we think of the consumption path of people facing such a collapse as the product of a sequence of discrete production decisions similar to that described in (20), it will be similar to that in fig. 9 where \(C\) denotes consumption, \(c\) denotes the irreducible subjective poverty line, \(C(k = i)\) the consumption path selected in the \(i\)th period, and \(C(k)\), the outer envelope of the \(C(k = i)\), the actual consumption path over the relevant time horizon. The effect of such a sequential approach is that the poverty determined discount rate is driven higher and higher with each decision. This is, in fact, similar to the consumption paths that Strotz (1955–56) described for 'spendthrifts' – those with perversely high rates of time preference – in that in each period the costs of present activity is deferred to a later date. Strotz saw this as a problem of inconsistency in optimal intertemporal consumption plans made at successive dates. In the present case, however, it represents quite consistent and rational behaviour. Bearing in mind that the agents concerned are assumed to be in subjective poverty, they will seek to maximise the number of periods in which minimum subsistence needs are satisfied, and to do this through choice of activity levels, the future costs of which are an indirect measure of their willingness to dissave. In other words they will try to stay alive for as long as possible. Nor is there reason to believe that the consumption paths selected will be anything other than optimal. The final value of consumption may well be zero, implying extinction, but this does
not mean that agrarian producers are not doing the best they can given the state of nature and range of options open to them.\textsuperscript{7}

5. Concluding remarks

Famine is evidence of extreme poverty. Since the work of Sen (1981) we may be reasonably confident that it is not necessarily evidence of the collapse of agricultural or pastoral output – food availability decline. This paper suggests, however, an even more disturbing causal relationship between extreme poverty and the state of agricultural or pastoral resources in open agrarian economies that is worth further study. It now seems clear that the dynamics of open agrarian economies are rather more complex than the early (quasi) stable equilibrium models of such as Leibenstein would suggest, and that causality between poverty and resource degradation can run both ways. We have seen, for example, that a collapse in the trade entitlements of agrarian producers may prompt them to increase the level of intensity with which the land is exploited even if this imposes costs in terms of reduced productivity in the future. In the extreme case where the system is both locally and globally unstable, these costs can be fatal. Indeed, if we apply the logic of exhaustible resource theory to the problem, given the distorting effects of poverty, we cannot avoid the conclusion that in the Sahelian and similar cases people have set themselves on to what Pearce has called an ‘optimal path to extinction’.

The collective response has been to avert disaster so far as possible by emergency relief, but this will do nothing to avert a recurrence of the problem in the future. Yet, if the source of the problem is the opening of agrarian economies dependent on fragile ecological systems, the solution ought to lie in the arena of trade and transfers. The compensation principle is, for example, a powerful ally in arguments for aid in cases where the gains from trade are uniformly negative for one county. By this principle trade will always be superior to autarky since there exist a system of transfers that would ensure that everyone could be made better off. But the compensation has to be made if trade is not to impoverish rather than enrich. The appropriation of the gains from trade in the advanced industrial economies, with occasional disbursements of aid or emergency relief to the traditional agrarian economies in times of famine, is no guarantee against the collapse of

\textsuperscript{7}Given the objective described in the text, such a time path would not contradict Bellman’s principle of optimality. The latter requires that whatever the initial state and decision are, the remaining decisions at any point in the path must constitute an optimal policy with regard to the state resulting from the first decision. Each segment of the time path must itself be optimal, no matter what has gone on before. In this case the optimal policy requires quite simply that the individual maintain consumption at the minimum subsistence level by dissaving for as long as possible.
the latter. The problem, as Sen points out, lies in the entitlements of agrarian producers in these economies. It is of crucial importance to secure a set of entitlements – whether by appeal to the compensation principle or not that will provide those producers with the incentives to operate at sustainable levels, and to search out forms of insurance against environmental fluctuations that do not themselves undermine the potential gains from trade.

References