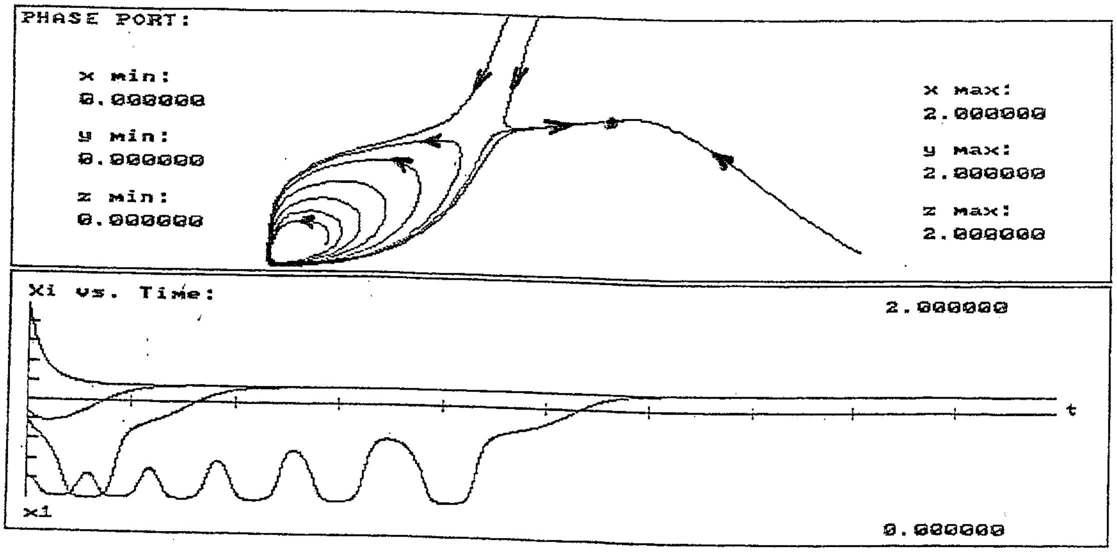


Figure 4.4c $\mu = 1.25$. The loop is broken. All the trajectories are attracted to the high level stable node.

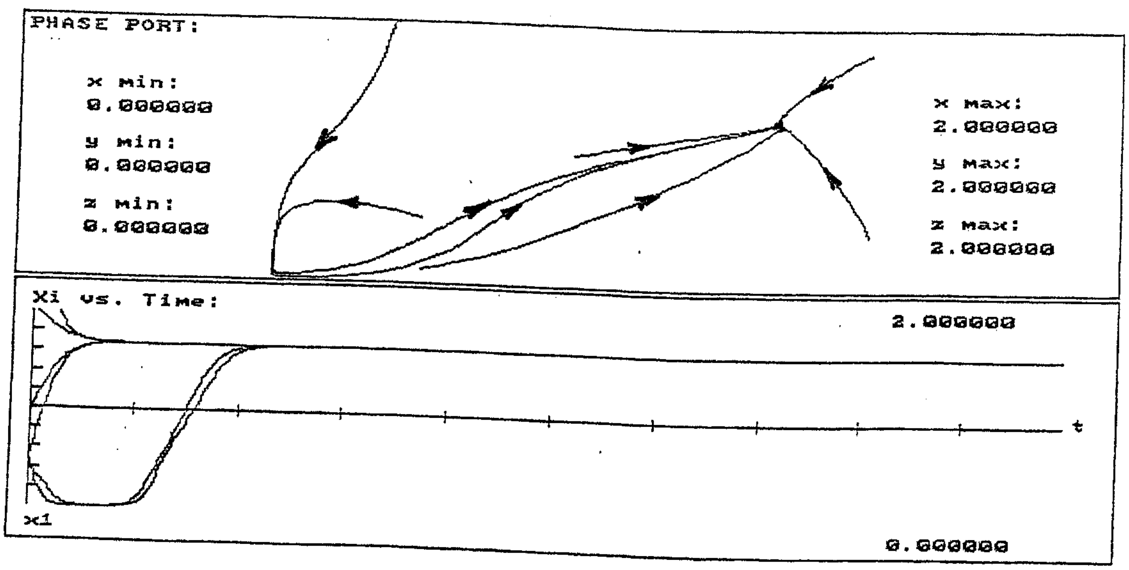


Figure 4.4d $\mu = 1.3$

3. Escape Strategy

Consider an economic system with constantly low agricultural and industrial income. Direct investments do not help to improve the system performance. This is a situation described as a *low-level economic trap* first described by Nelson [11]. Knowledge about bifurcations occurring in the system allows the following four part strategy for escape from this trap.

(a) Consider that the trapped system has only one attractor located at low levels of A and I (like Fig. 4.1). That is why direct subsidies to A and I from outside the system do not help. They only serve to change the initial conditions of the system, but do not create any other attractors. Some time after such income transfers (very short if the equilibrium is a stable node, or not so short if it is a focus), the system rolls down to its original (before subsidies) state.

Under these circumstances, subsidies can achieve political, social or ethical objectives. They can only achieve economic objectives if designed in the form of bridge financing which enable structural improvements to the resiliency of businesses. Resiliency is increased by increasing economic recovery rates a and b.

(b) When economic recovery rates in the system are brought to a suitable level, government policy should be directed toward increasing relative agricultural productivity (growth of μ). Then Hopf bifurcation occurs and the system may be expected to spend at least half of its time at comparatively high levels of A and I.

(c) The third part of the strategy is to change farming practices to increase the ecospheric recovery rate, creating a new attractor, a high level stable node (Fig. 4.2 and 4.3). Once it is created, direct subsidies could help to boost the system's performance, because favorable initial conditions are attracted to the node.

(d) Growth and economic stability are achieved when all possible initial conditions are driven to the high level node. This may be achieved with a productivity strategy. It results in a homoclinic bifurcation after which the high level node becomes asymptotically the final state for all the trajectories of the system.

Now (Fig. 4.4d) the system is trapped at the desirable high level of wealth. Further growth would require escape from this 'high level' trap. Steps (a-d) could be repeated at the higher level. The system could be sustained at its higher level by sustaining the values of all the parameters in the system, especially relative productivity.

V. Globalization Effects

Globalization is modeled as the consequences of relationships between the system in question and a higher order system. Globalization means opening and speeding up transactions flowing from the relationship. Transactions happen within the processes of learning, adoption of technology, and information. Transactions also include sanctions from falling behind, and rewards from achieving competitive advantage. Transactions involve the cascading effects on the system in question, of oversupply or shortages within the higher order 'global' system. Some of the consequences of globalization are the transfer of economic power to and away from systems, changes in currency exchange, interest rates and tax treatment, costs of social programs and environmental regulation within higher order systems.

Local agricultural systems become part of a larger, global system directly through trade liberalization and less directly through technology. Change taking place in the global system may affect the values and behaviour of some parameters of the smaller local system. These global changes may show up in local systems in the form of external impulses, introducing non-autonomous features into the local system dynamics. These impulses are modeled here as periodic disturbances of some structural parameters. Let us examine now, how to cope with the undesirable effects of global impulses.

1. Productivity Impulses

Agricultural productivity changes through time based on the business cycle, markets, weather and patterns of adoption of new technology. Although learning is cumulative, its translation in terms of productivity reflects the motivation of farmers, their assessment of future profitability and affordability.

The evidence on the behaviour of agricultural productivity over time is of gentle oscillation around a trend associated with the general industrialization of agriculture (Figure 4.5). This oscillation is modeled in the simplest way by a sine function without the trend.

$$\mu \to \mu(t) = \mu\left(1 + h \sin \frac{2\pi t}{T}\right), \tag{4.3}$$

where h is the amplitude and T is the period of the oscillation.

These oscillations may have their most adverse effect on system performance, when the ecospheric recovery rate is not high enough. This can happen when the technology itself damages ecospheric recovery, or farmers lose touch with their natural resource environment. The values of A and I oscillate near a low level equilibrium, spending a lot of time with almost zero income (Fig. 4.6a).

The same system with constant $\mu < \mu_0 \approx 1.1$ oscillates with slowly decreasing amplitude, and its trajectory asymptotically approaches a low level equilibrium analogous to trapping. Such a situation with $\mu = 0.5$ is shown in Fig. 4.1c. Constant μ greater than μ_0 corresponds to the dynamics dictated by the presence of a limit cycle (see, e.g., Fig. 3.4a). In this case the values of A and I oscillate with a comparatively large amplitude near the same low level equilibrium. Compared to the case of oscillating μ, the system spends more time at relatively high values of A and I.

Increasing the ecospheric recovery rate while μ oscillates results in oscillations in agricultural wealth with larger amplitude. The higher levels of A and I persist over longer periods of time (Fig. 4.6b).

Consistent attention to ecospheric recovery leads eventually to comparatively smaller oscillations near a much higher level equilibrium (Fig. 4.6c). Thus, the undesirable effects of oscillating μ may be turned to a system's advantage if the recovery rate of the ecosphere is sufficiently high.

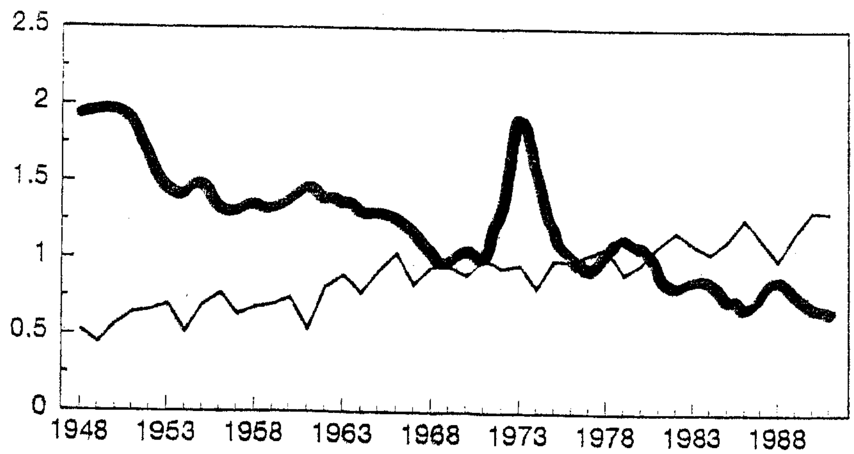
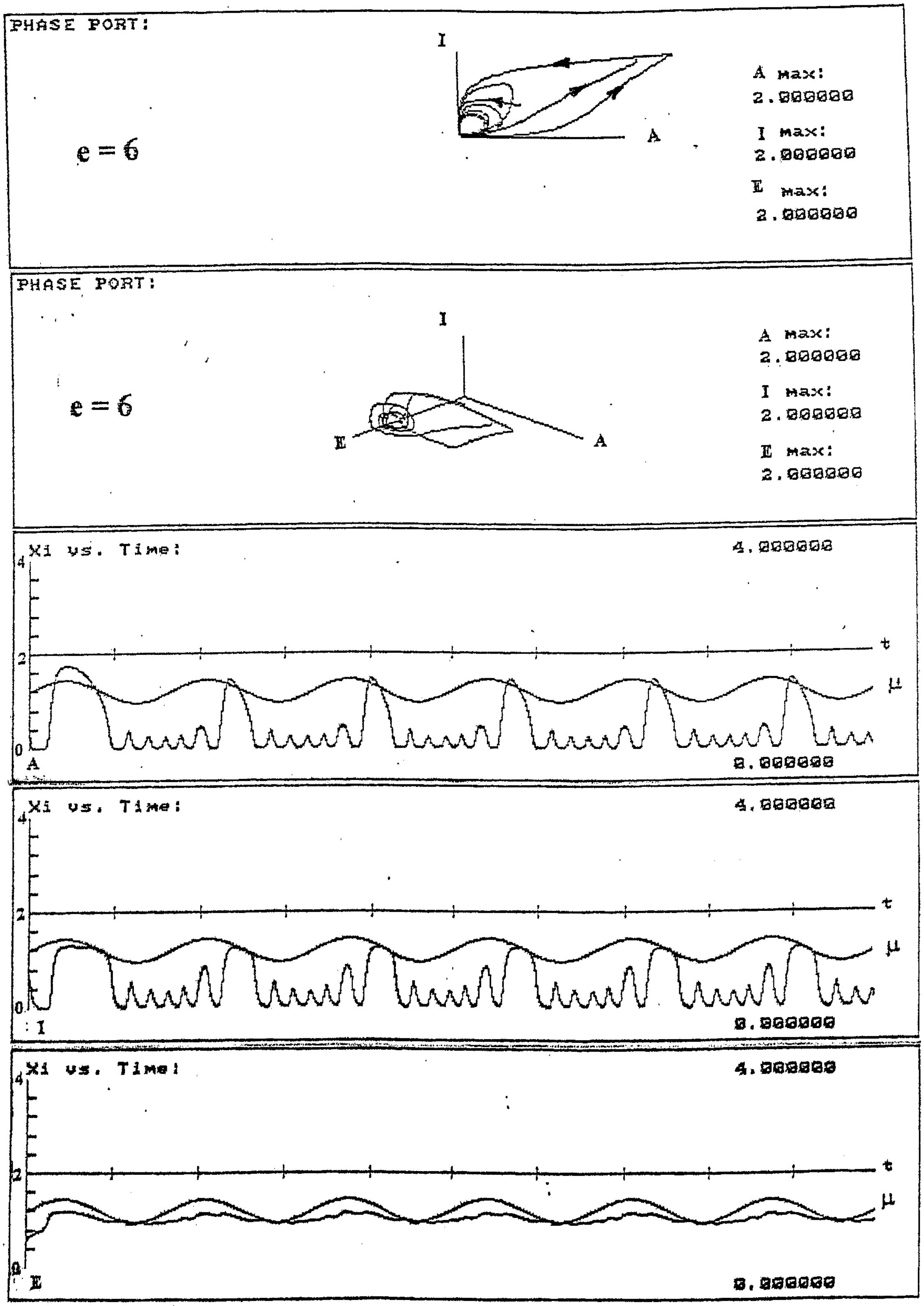


Figure 4.5. Productivity (—) and terms of trade (▬) in prairie agriculture [12].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I
A
A max:
2.000000
I max:
2.000000
E max:
2.000000
PHASE PORT:
e = 6
I
E
A
A max:
2.000000
I max:
2.000000
E max:
2.000000
Xi vs. Time:
4.000000
t
μ
A
0.000000
Xi vs. Time:
4.000000
t
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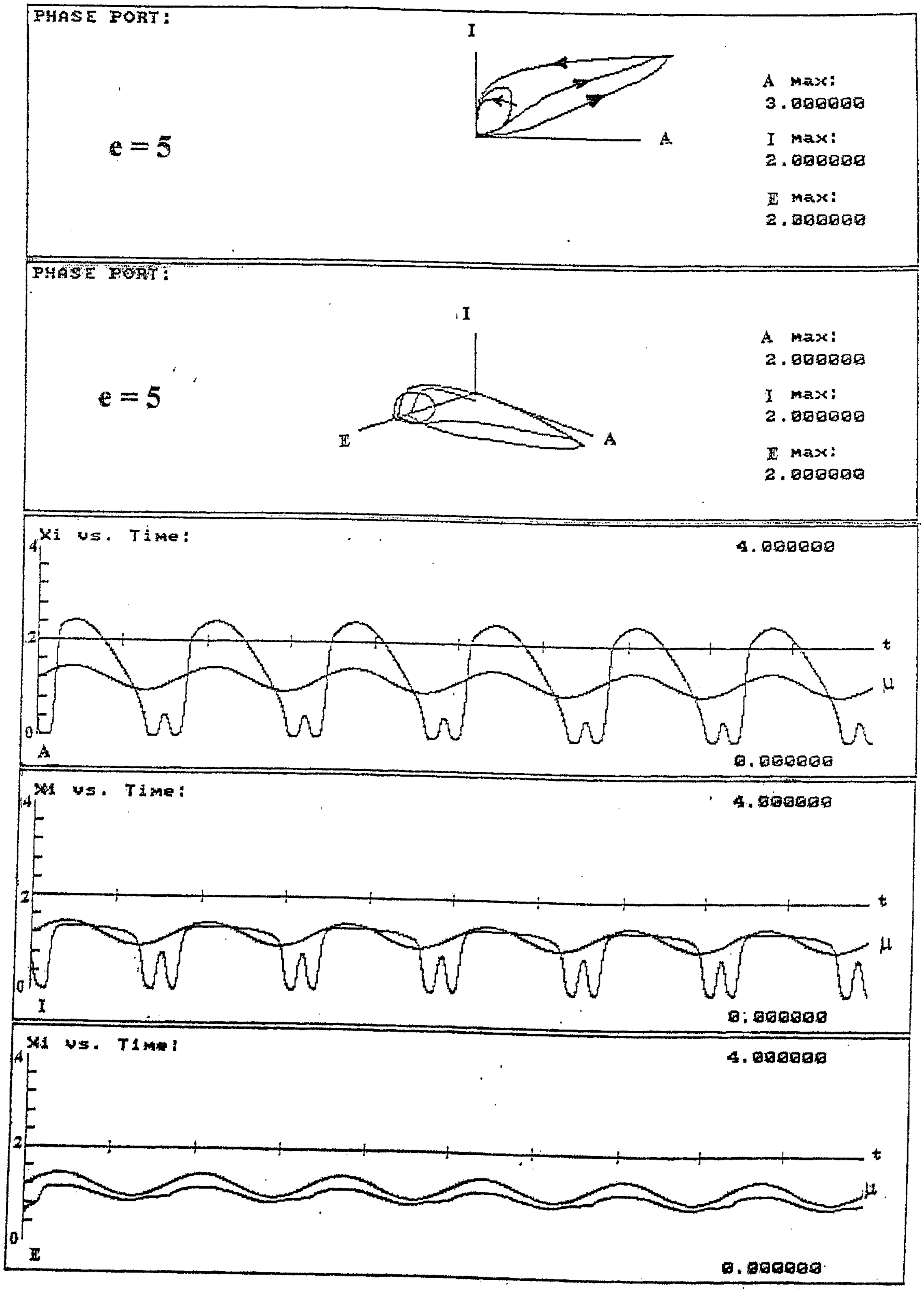
Xi vs. Time:
4.000000
t
μ
E
0.000000

Figure 4.6a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A max:
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I max:
2.000000
E max:
2.000000
PHASE PORT:
I
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e = 5
A max:
2.000000
I max:
2.000000
E max:
2.000000
Xi vs. Time:
4.000000
4
2
0
t
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A
0.000000
Xi vs. Time:
4.000000
4
2
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I
0.000000
Xi vs. Time:
4.000000
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2
0
t
μ
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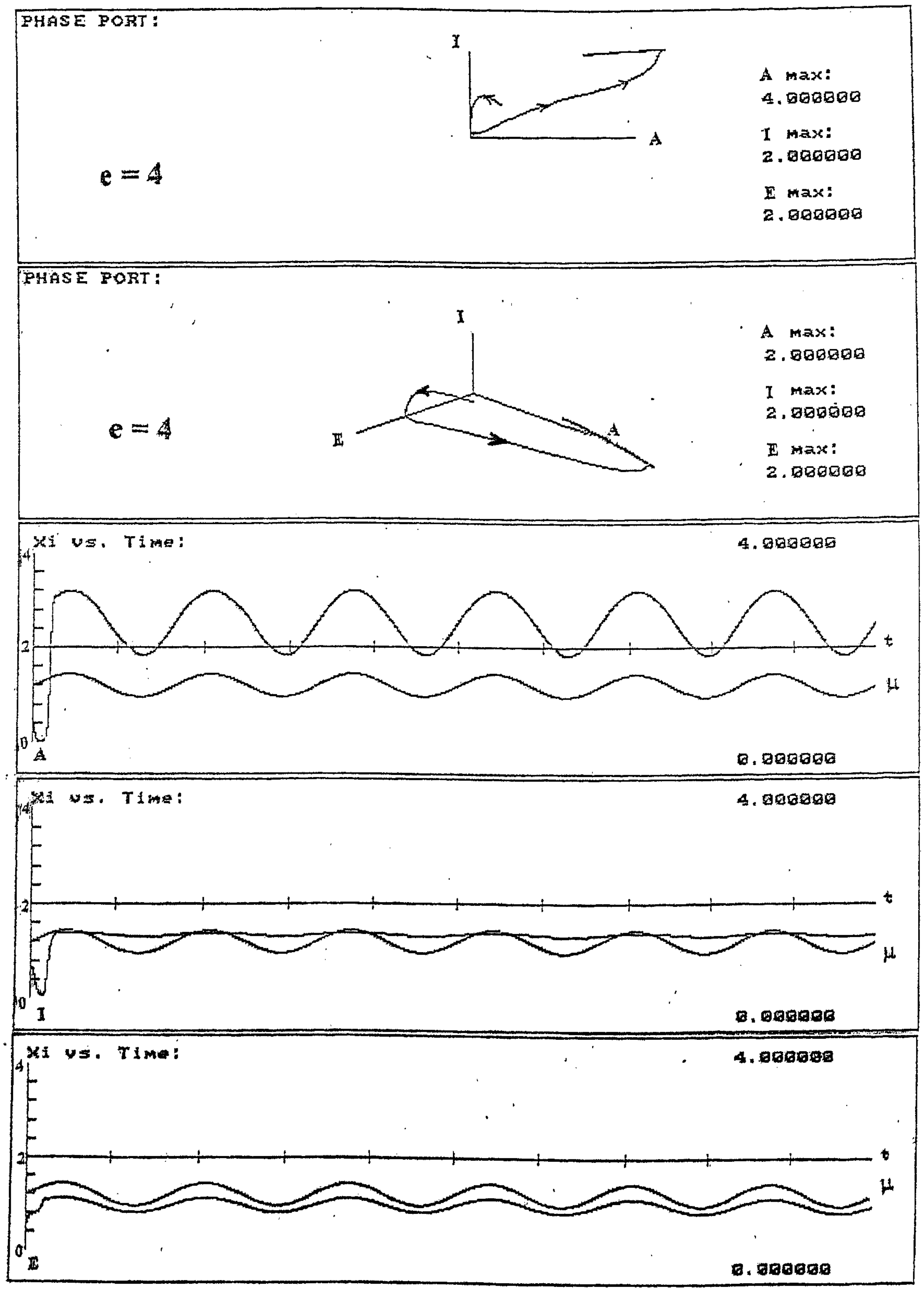
Figure 4.6b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I max:
2.000000
E max:
2.000000
e = 4
PHASE PORT:
I
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2.000000
I max:
2.000000
E max:
2.000000
e = 4
Xi vs. Time:
4.000000
4
2
0
t
μ
A
0.000000
Xi vs. Time:
4.000000
4
2
0
t
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I
0.000000
Xi vs. Time:
4.000000
4
2
0
t
μ
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0.000000

Figure 4.6c

2. Terms of Trade and Globalization

For simplicity we may also model the impulses transmitted through terms of trade (Fig. 4.5) from exposure to the global economy by means of harmonic oscillation of the value of γ, agricultural prices, keeping industrial prices δ constant

$$\gamma \to \gamma(t) = \gamma\Big(1 + g \sin \frac{2\pi t}{T}\Big). \tag{4.4}$$

The immediate negative effect of these oscillations is reduced predictability of the system. For $\mu = 1$ and $g = 0.5$, the system has two periodic attractors, one at a high level of wealth and one at a low level (Fig. 4.7a). It is interesting to notice that the lower attractor is a so-called double loop, an indicator that a period doubling bifurcation [5] has occurred as a result of the loss of autonomy of the system.

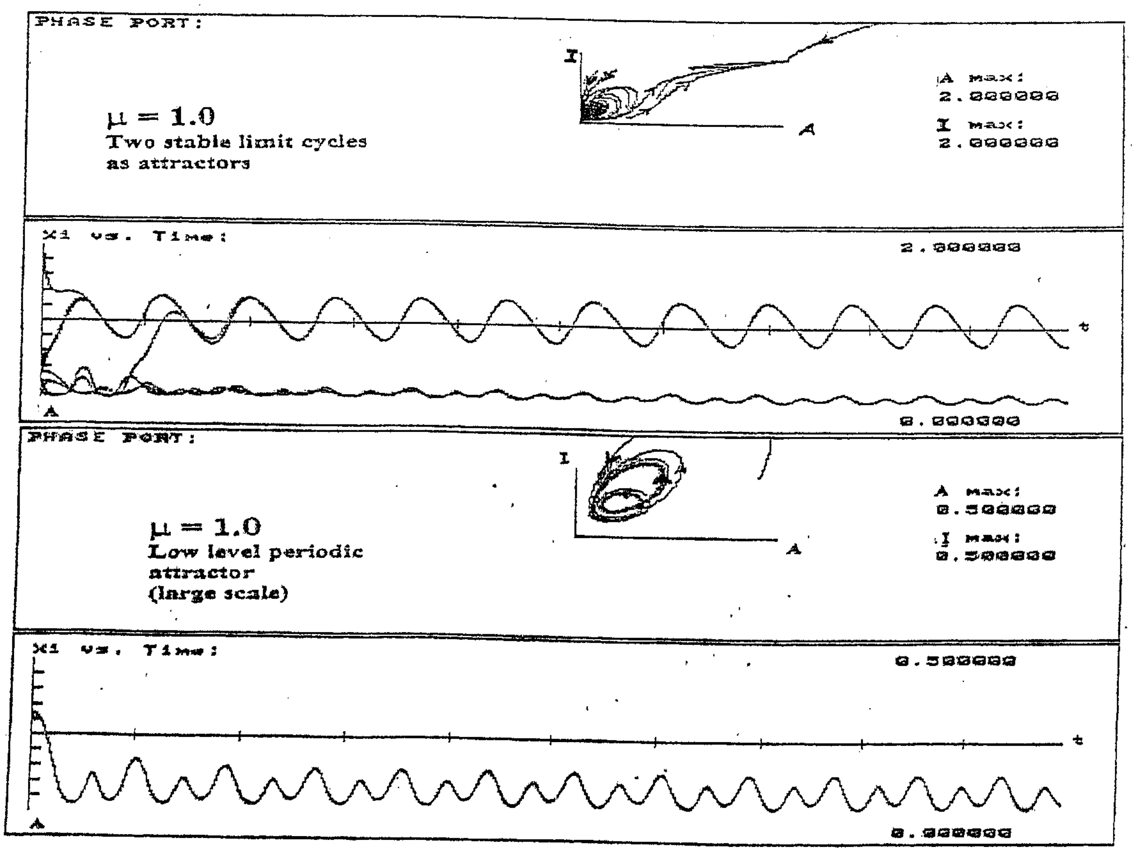

Figure 4.7a

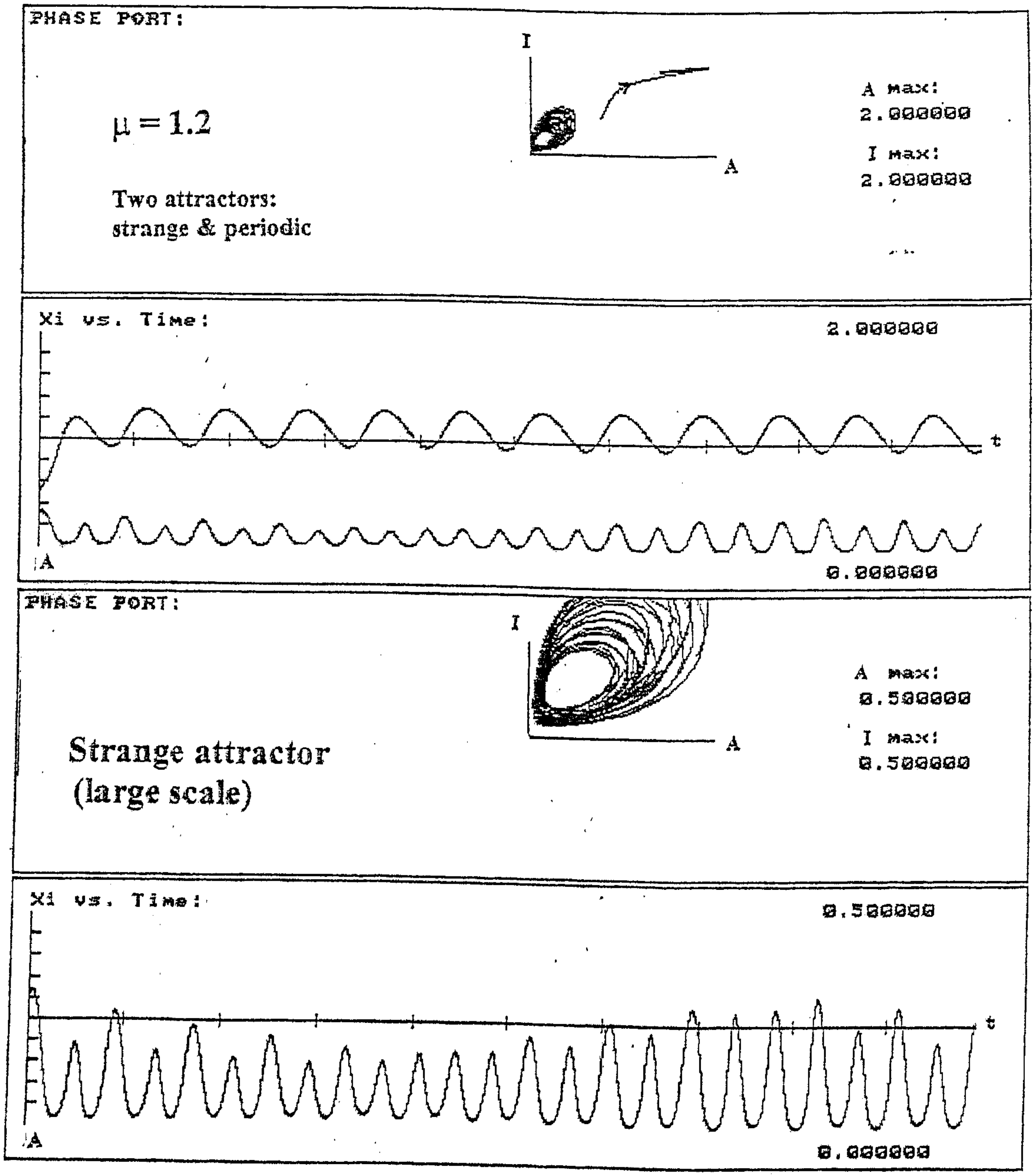
PHASE PORT:
$\mu = 1.2$
Two attractors:
strange & periodic
I
A
A max:
2.000000
I max:
2.000000
Xi vs. Time:
2.000000
t
A
0.000000
PHASE PORT:
Strange attractor
(large scale)
I
A
A max:
0.500000
I max:
0.500000
Xi vs. Time:
0.500000
t
A
0.000000

Figure 4.7b

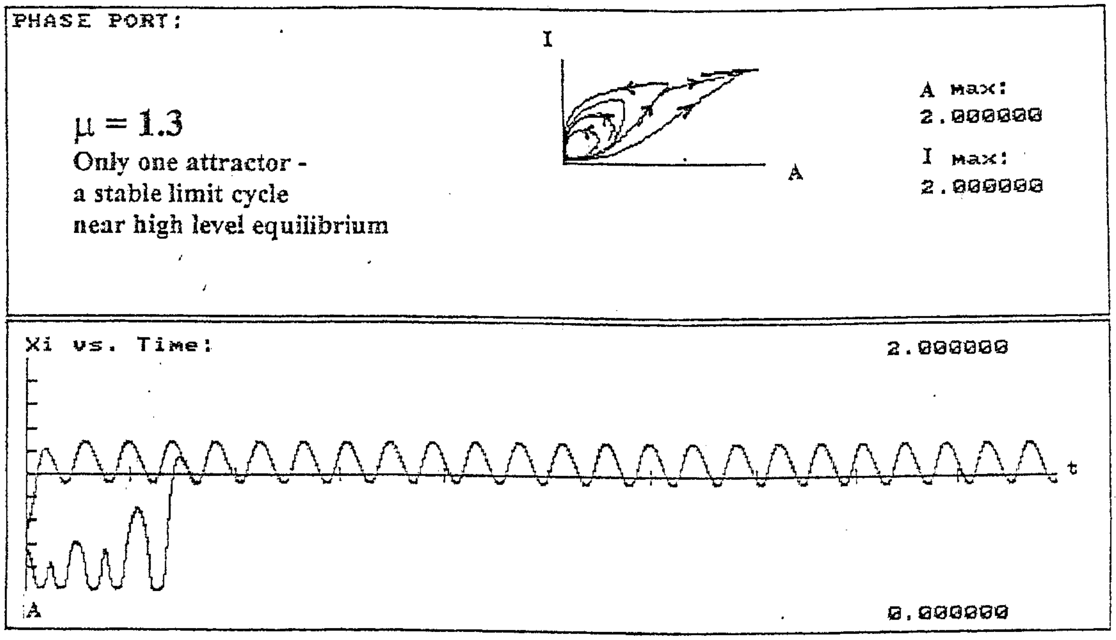

Figure 4.7c

If μ increases beyond $\mu = 1$, to the value of 1.2, a cascade of these bifurcations takes place and the lower attractor becomes *strange* (Fig. 4.7b). The trajectories fill part of the phase space in a seemingly chaotic manner. Predictability is poor: given that the two trajectories start at very similar initial conditions, and may then diverge far away from each other.

The cure lies in the further increase of μ : where μ reaches 1.3, the strange attractor disappears and all the trajectories end up oscillating with a small amplitude about a high level equilibrium (Fig. 4.7c).

It should be noticed that lower values of g allow strangeness to persist in the wider range of the other parameters e.g., μ. Fig. 4.8 is an example with a strange attractor for $g = 0.4$. It looks "stranger"; – the tangle is "more chaotic" than in Fig. 4.7b with $g = 0.5$.

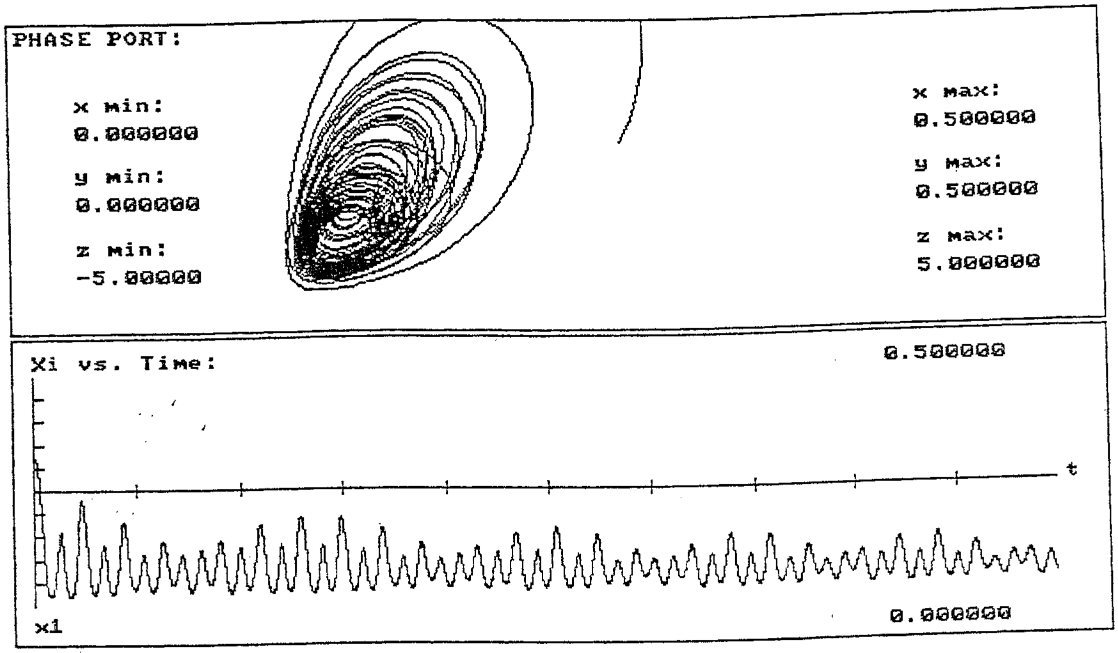

Figure 4.8

In contrast, larger values of g lead to high-amplitude oscillations avoiding strangeness (Fig. 4.9).

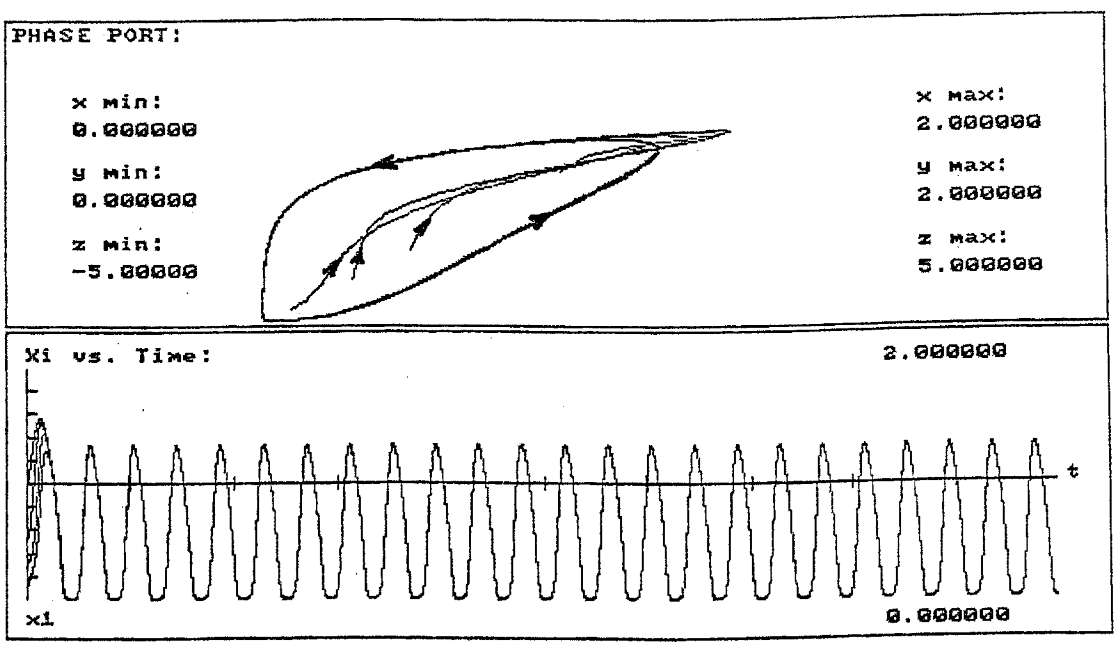

Figure 4.9. $\mu = 1$; $g = 1.2$. Though μ is low, there are no strange attractors.

VI. Conclusions

Natural resource economies draw upon the ecosphere at the same time as they trade with industrial systems which supply their inputs and buy their outputs. Both the input and output markets linking a natural resource system, such as agriculture, to industrial systems transact information and technology as well as materials. This research has explored management opportunities, associated with the parameters of these three systems, which may lead to sustained improvements in performance. The management opportunities were tested under conditions of economic globalization using rudimentary impulses from markets and technology.

The first conclusion substantiates earlier work with these types of complex dynamical systems models. The most common type of equilibrium is a form of limit cycle or focus. No amount of 'blind' subsidies can change these equilibria, nor their stability conditions. Low levels of system performance require changes to the values of selected parameters, obtainable only through strategic combinations of market restructuring to ensure greater competition, more aggressive recovery to the ecosphere, and more robust business resilience to shocks. Many strategic policy and business options are available in the form of diverse combinations of parameter values. The choice of combination, particularly under conditions of global liberalization of trade and technology, depends on which parameters managers feel they have the most control over.

The second set of conclusions is about predictability. Predictable outcomes are a precondition for capital investment. Improvements in predictability are closely associated with moving to higher levels of performance, especially as a consequence of breaking out of low level income traps. However, stable but oscillating agricultural prices can reduce predictability. Stronger environmental recovery offers promising results for reducing uncertainty in outcomes. The main beneficiary of agricultural income predictability is the industrial system, implying that policy measures to improve predictability should be paid for from industrial incomes or transactions taxes with strongest incidence in metropolitan economies.

The third set of conclusions is about escape from low level equilibrium traps. Trapping is an outcome of dynamics. Therefore static models appear not to be useful for studying problems of underdevelopment. Escape lies not in the absolute values of the attributes of a low income economy, but in the relative values among the systems and between the trapped economy and its trading partners, if indeed it is an open economy.

Policy sequencing is the optimization problem, not the question of finding an optimum policy per se. Environmental and productivity policy measures are somewhat substitutable within and between time periods, with outcomes particularly sensitive to understanding environmental recovery processes. Strategic positioning of a natural resource economy like agriculture for insurability appears to be an important precondition to sustaining rehabilitation investments for the environment. Once again, the industrial system benefits most from these approaches to agricultural and environmental policies.

The final conclusion is that the CDS approach is producing increasingly tractable strategic insights for low and unpredictable income for agriculture, or for any economy with particularly close dependence on the ecosphere. These problematic outcomes continue to beset rural economies despite more than half a century of static modelling and enormous income transfers, especially to agriculture. The CDS approach provides plausible explanations for why these policies do not work and offers new directions for analysis.

Acknowledgments

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