The Limits to Growth Hypothesis:

Some Empirical Evidence

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I. Introduction

Economists from Smith to Keynes were practically unanimous in predicting that economic growth in the world would first slow down and then come to a standstill. Although they were agreed, it was very diverse reasoning that led them to this prediction. For Ricardo, it is fixed supply of land and diminishing returns in agriculture; demographic improvidence for Malthus; collapsing markets coupled with growing reserve army of the unemployed for Marx; extinction of entrepreneurial spirit for Schumpeter; exhaustion of natural resources for Jevons and insufficiency and instability of investment opportunities for Keynes.

It is surely one of the most dramatic reversals in the history of human experience that the pessimism of an oncoming stationary state was replaced by confidence in continued economic growth. To quote Lave (1966) "...In one mighty blow, Solow (1957) cut the Gordian Knot and banished poverty from our midst. No wonder the classical economists were wrong; ninety percent of the increase in productivity was neglected."

However, the optimism about continued growth through technological advancement began to wear off in recent years. The depletion of the environmental stock made some economists wonder if the world was running again into a stationary state, circumscribed by the limits of exhaustible resources. The most

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vocal statement, on this problem, was made by Meadows et. al; (1972) in a study entitled, *The Limits to Growth.* The study concluded that, "If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached some time within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity."

Are the limits to growth really circumscribed by the scarcity of non-renewable resources? Does the prediction of an oncoming stationary state turn out to be unnecessarily pessimistic? These pressing questions have generated considerable interest as evidenced by the recent empirical and theoretical literature on growth with exhaustible resources. In this study we attempt to present some empirical evidence that tends to support the hypothesis that economic growth in evolving entropic systems tends to follow a cyclical path of overlapping S-curve patterns where rise and fall of growth rate alternate each other. In Section II we examine the issue of limitability of resources and future growth possibilities of societies. Section III presents a critique of the 'Doomsday Models.' Section IV presents some econometric evidence on the rise and fall of systemic growth and Section V ends the paper with some concluding remarks.

II. The "Running Out" Syndrome

In a closed system in its most general form, the law of entropy says that if any event occurs, it is because there exists a potential for its occurring; when once the event occurs it uses up the potential for its occurring and it cannot occur again unless the potential necessary for its occurring is recreated. The Law of Conservation says that given a fixed quantity of anything, all that can happen is rearrangement. It is generally argued that the applicability of these laws of entropy and conservation to the economic process is irrevocable and that no amount of increase in substitution and (or) efficiency in use of resources can basically alter this fact. Georgescue-Rosen (1976) writes: "Whatever resources or arable land we may need at one time or another, they will consist of accessible low entropy and accessible land. And since all kinds together are in finite amount, no taxonomic switch can do away with that finiteness."

First of all, we do not pretend to claim that the applicability of the laws of entropy and conservation is totally unwarranted. However, we do venture to say that in open systems like the earth, these laws are not applicable with absolute strictness, for the process of evolution should not be considered in isolation from the process of pollution. Just as the anaerobic forms of life produced oxygen as a pollutant which triggered the development of oxygen-using organisms, entropic processes of using up potential can cause to create further potential.

The issue under investigation is not the "taxanomic switching," but the status of the categories "running out" and "resources." As Solow (1979) puts it, "In fact the "running out" figure of speech is geologically inappropriate in most instances. There is much more copper in the earth's crust than the human race is ever likely to need." Page (1973) has presented an account of responsible estimates of broader possibilities: "Seawater has been estimated to contain 1000 million years' supply of sodium chloride, magnesium and bromine; 100 million years' of sulphur, borax and potassium chloride; more than 1 million of molybdenum, uranium, tin and cobalt; more than 1000 of nickel and copper. A cubic mile of seawater contains around 47 tons each of aluminum, iron and zinc; given around 330-350 million cubic miles of such water, we are talking around 16,000 million tons each. Such estimates tend to exclude special concentrations such as the Red Sea brines and sediments; these alone contain perhaps $2000 million worth of zinc, copper silver and gold and perhaps ten times this level at current market prices.....The most pressing of the limits to growth in resource usage are not geological.....The above figures may be horribly in error, but it is inconceivable that the principal qualitative point is entirely erroneous."

Of course a civilization totally dependent on a limited amount of exhaustible resources can never be permanent. Any limits to growth that may exist are likely to come from man's ability (both economic and technological) to exploit these resources. In reality resources do not exist as physical facts, but only as the result of human appraisal. A resource becomes a physical fact only in relation to man's needs and his ability to use it in relation to his environment. That the use of metals can be extended by recycling is already an established fact of life. In industries such as canneries, meat packers, lumber and pulp, increased labor and capital can substantially reduce the material input requirements and in effect become good substitutes for these inputs. Thus technological factors play a double role in the growth process of socio-economic systems. While those factors broaden the range of choice of feasible change-paths, they also serve to lead the systems toward increasingly higher order of sophistication for systemic stability. Knowledge and technical ability supported by socio-economic structure advance to make available the necessary negentropy. Socio-economic systems possess the capability to adapt and develop through time by a constrained process of volitional selection. As long as investment takes place in the production of knowledge the cognitive capacity is likely to take the human race to the "far off divine event to which the whole creation moves."

III. A Critique of the 'Doomsday Models':

Meadows *et. al.* expressed widespread concern that the world is rapidly approaching the limits to growth set by the exhaustion of non-renewable resources and destruction of the biosphere. The prophets of 'Doom' made a frontal attack on economic growth as a policy objective, arguing that continued growth was not merely undesirable but, before long, impossible. This conclusion followed from their assumptions and their assumptions were "very much a reflection of their generally pessimistic view of the world" (Cole and Curnow (1973)).

The reliability of the predictions of the Doomsday Models has been seriously questioned by economists for the simple reason that there is no trace of information on econometric estimation and testing of hypotheses. Allowance was not made, in the models, for factors mitigating resource scarcity; factors such as technical change allowing for increasing efficiency of resource use, increasing natural resource discovery permitting use of formerly unusable resources, etc. Further these models ignore resource substitution in production and consumption activities. Furthermore, the most noticeable defect of the Doomsday models is the absence of any influence of a pricing or planning mechanism. Finally models that are allowed to run for 20 or more years, instead of a few quarters ahead, become part of fancy exercises, rather than genuine forecasts.

IV. The Rise and Fall of Economic Growth:

It is misleading to say that the world will "run out" of natural resources, 'since the "limits" themselves are no longer fixed, but grow exponentially too' ((Kaysen (1972)). Throughout the history, technological progress and investment in R & D have created new resources. As per capita income rises, diminishing returns are likely to set in thus increasing costs of economic growth relative to its benefits. Limits are set to these costs by accepting a slow down in the economic growth; in fact this may represent a temporary slow down in growth since it is quite possible that following the slow down, per capita growth could once again bounce back to a rise due to technological advances, increased substitution in consumption and production of inexpensive for expensive resources. The historical record of technological change and its responsiveness to changing market conditions provide sufficient evidence in this direction. The secular course of economic growth in evolving entropic systems tends to trace overlapping S-curve patterns. Systems tend to grow more rapidly in stages when negentropy is very high and more slowly as it becomes less available. This relative availability of negentropy depends in large part upon technology and institutions the advances and adaptations of which enlarge the entropy system and allow the material transformations necessary for secular growth to continue. Thus we hypothesize that a system's growth follows a cyclical pattern of overlapping S-curves; rise and fall of per capita income growth marks the progress of societies. A society that can generate and sustain its productivity increases can escape the limits to growth but for temporary declines during transitional periods of technological epochs.

SOME EMPIRICAL EVIDENCE: In this section we present a simple model of evolving entropic systems tracing overlapping S-curve patterns of growth. At the minimum, we use a third degree polynomial to adequately approximate the overlapping S-curve pattern. The model is estimated using data pertaining to a sample of 120 countries. The independent variables are the investment-income ratio and the first, second and third powers of an index of the level of development. The dependent variable is measured by the per capita GNP growth rate. Investment-income ratio is introduced to capture the increased capacity effects of higher investment on the growth rate. Relative per capita income and relative per capita energy consumption are used as two different proxies for the level of development.[1]

The model we estimate is as follows:

$$y = a + b\sigma + c x_i + dx_i^2 + ex_i^3 \qquad (1)$$

$$i = 1, 2$$

where
y = per capita GNP growth rate
σ = investment-income ratio
x_1 = relative per capita GNP
x_2 = relative per capita energy consumption.

According to our hypothesis we expect the following signs on the coefficients of (1): $a \lesseqgtr o$, $b > o$, $c > o$, $d < o$, and $e > o$. A positive but statistically significant estimate of 'e' is apparently sufficient evidence to suggest that the pessimism of the 'Doomsday Models' is characteristically unwarranted.

Table 1 presents the least squares results of equation (1):

In all experiments, the cofficients of the right hand side variables in equation (1) are statistically significant with the expected signs. Inclusion of the investment-income ratio on the right hand side has improved the goodness of fit. The results consistently indicate that the third degree polynomial is an excellent fit to the cross-sectional data on per capita income growth showing that the predictions of the Doomsday Models are unwarranted. The graphical version of the estimated equation (1) shows exactly the same growth pattern on next page.[2] Thus the statistical analysis presented here supports our contention that a society seemingly follows a cyclical pattern of growth with rise and fall of growth alternating each other.

V. Conclusions

Number of economists, sociologists, political scientists and others have suggested that the world is rapidly approaching the limits to growth set by exhaustion of non-renewable resources,

1 Relative per capita income (energy consumption) is defined as the ratio of a country's per capita income (energy consumption) to that of the U.S.

2 We have presented only one graph as the other cases are exactly similar to this.

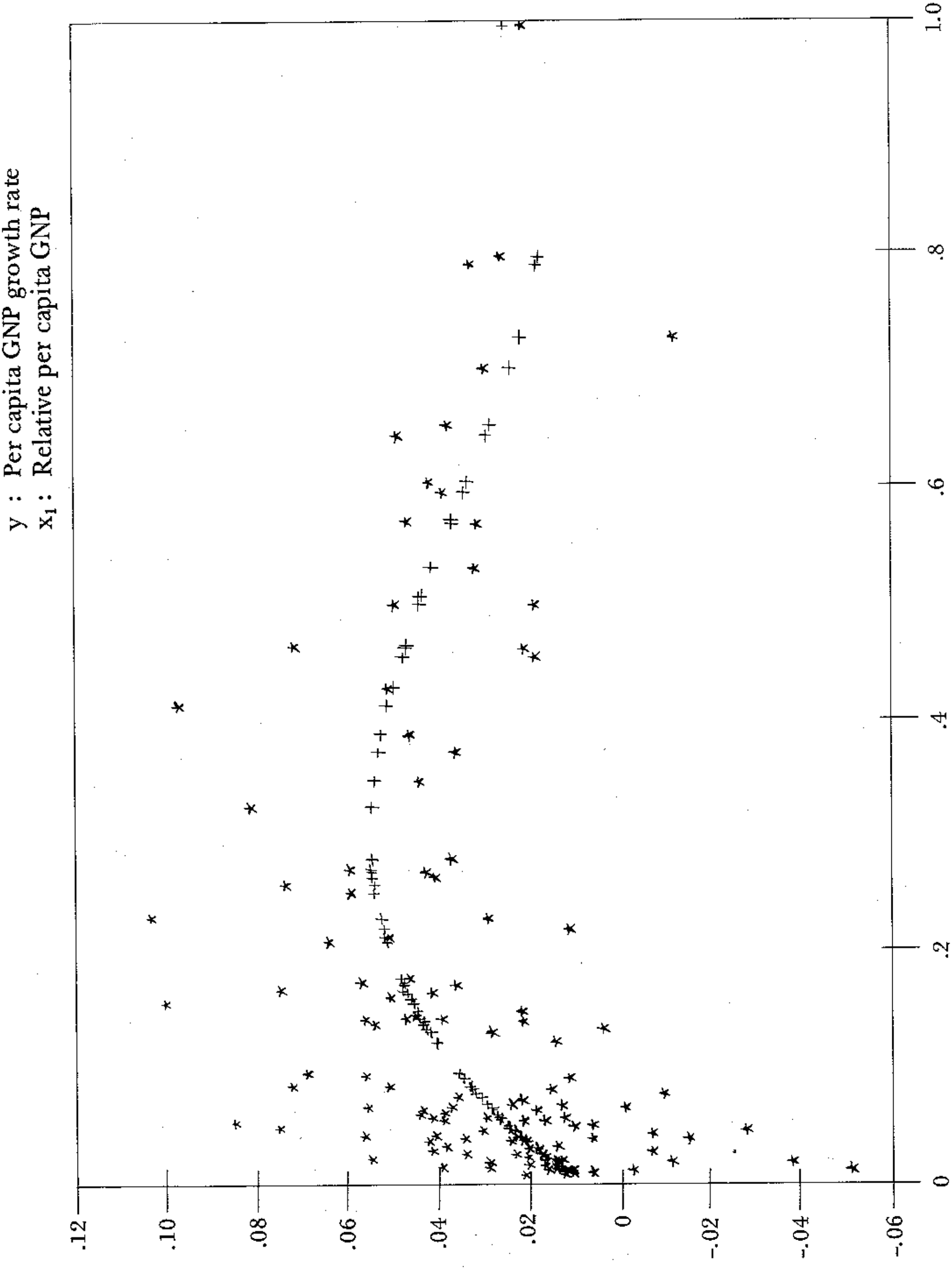
Table 1

LEAST SQUARES RESULTS OF (1): DEPENDENT VARIABLE IS 'y'

	Model 1				
	Constant	σ	x	x^2	x^3
(i)	.009 (2.16)	–	.339 (5.52)	-.752 (-4.23)	.428 (3.17)
				R^2 .270	F 14.3
(ii)	-.009 (-1.57)	.135 (4.21)	.241 (3.89)	-.556 (-3.29)	.330 (2.57)
				R^2 .367	F 16.7
	Model 2				
(iii)	.019 (5.56)	–	.292 (4.48)	-.774 (-3.78)	.493 (3.17)
				R^2 .171	F 7.9
(iv)	-.004 (-.71)	.157 (4.71)	.158 (2.38)	-.451 (-2.25)	.294 (1.98)
				R^2 .305	F 12.6

The numbers in parentheses are t values.

population explosion, pollution and other problems. The 'Limits to Growth Hypothesis' generated considerable interest as evidenced by the recent empirical and theoretical literature on growth with exhaustible resources. In this study we made an attempt to


y : Per capita GNP growth rate
x1 : Relative per capita GNP
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
0
.2
.4
.6
.8
1.0

examine the issue presenting some empirical evidence. We hypothesized that systemic growth seemingly follows a cyclical pattern of overlapping S-curves with rise and fall of growth alternating each other.

We argued that a society capable of generating and sustaining productivity increases through investment in the production of knowledge can escape the limits to growth. The predictions of the doomsday models that the world is rapidly approaching the limits to growth were not reliable as these models lack proper scientific statistical analysis. Their conclusions were based on assumptions that reflect an unnecessarily pessimistic view of the world. A cross-section model of cyclical growth represented by a third degree polynomial was estimated in four different forms using data on one hundred and twenty countries. The results do not seem to reject our hypothesis of cyclical pattern of systemic growth.

In sum, the ability of our socio-economic system to advance at a rate that will allow continued achievement of the system's functional objectives depends on the balance between necessary technology and its supportive institutions. Overtime, only the rate of advance changes. To avoid disfunction. systemic development must be directed towards increasingly complex and sophisticated models of organizational interrelationships. The process of achieving those modes of organization is necessarily constrained by cost considerations, since a particular organizational form is not preordained.

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