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INTRODUCTION: INDUSTRY, TECHNOLOGY AND GROWTH

Economic Growth

The world is changing at an unprecedented rate. This is a cliche than needs substantiating with detailed evidence; and today we shall attempt only a brief outline or what lies behind this assertion.

We are all familiar, to some extent, with the notion of geometric or exponential growth, but we often fail to grasp its logical implications. In an urbanised and industrialised country, we expect the gross product of our national economy to grow, on average, by a few percentage points per annum; and we are surprised and distressed if ever a negative growth is recorded. This means that we expect the gross product to follow an exponential or geometric growth path.

If such growth were proportionate, which is to say, if the relative proportions of the various goods and services that we consume were to remain unchanged, then we should also expect the quantities of the materials and the energy consumed in the processes of production to increase exponentially. We would expect the waste products of production and consumption to increase likewise.

In fact, the relative propositions of the various goods, services and waste products that result from economic activities are liable to change markedly in the process of economic growth. This poses a fundamental difficulty in economic measurement, which is called the index number problem. Because of changing proportions, there can be no unequivocal measurement of the relative sizes of two different economies or of the same economy at two points in time.

The consequence of these difficulties is that, in order to make meaningful comparisons, we must forsake measurements of value and resort to measurements of physical quantities. Examples are the annual production of steel or sulphuric acid, the quantities of kerosene and gasoline burned, the amount of electricity consumed, the number so domestic cattle slaughtered, the tons of grain harvested, and so on. In order to assess the performance of an economy in a finite world, we also have to determine the extent of its encroachment on the stock of depleteable resources and the extent to which it taxes the regerenative capacities of renewable resources.

The per capita consumption of energy and minerals has been increasing rapidly in the past 100 years. The consumption and the waste of foodstuffs has also been increasing more rapidly than has the global human population, but we can see that the benefits of this have been spread in a very uneven way amongst different groups of humans.

Some waste products have also been increasing markedly. The products of combustion resulting from our growing use of fossil fuels have been increasing disproportionately. This is leading to an unsustainable burden of atmospheric

carbon dioxide, which entails a potentially devastating increase in global temperatures. (We shall devote a considerable amount of time, in this course, to an analysis the causes and the consequences of the global warming.) There is also a small but menacing burden of chemical by-products that threaten us with metabolic and neurological damage and which may eventually undermine our reproductive fertility. (See Colborn et al. 1996)

From the perspective of the industrialised world, there is a tendency to regard the growth rate of Gross National product as an index of the rate of social and material amelioration. In taking this view, we often fail to adjust our figures of economic growth to take account of the growth of the population. That is to say, we are liable to regard the growth of GNP and the growth of per capita incomes as virtually synonymous.

The average annual percentage growth of population is by far the lower rate in the typical western industrialised country; and it makes little difference whether or not it is subtracted from the growth of GNP. This serves to avert our attention from one of the salient facts of the modern world.

The fact is that, in much of the non-industrialised world, the growth of the economy and the growth of the population are racing neck to neck, with the latter threatening to overtake the former. The growth of global population constitutes a global crisis. In 1945, at the end of the Second World War, there were roughly 2.5 billion people in the world. By 1975, the figure was 3.9 billion. By 2000, the figure had exceeded 6 billion. Most of the additional population has been born into third-world poverty.

For many years, and certainly for most of the 20th century, western societies were conditioned to see no end of the process of growth and material amelioration that they have experienced. There was an expectation, which was fading gradually towards the end of the century, that the less developed countries of the so-called third world could be expected, sooner or later, to join the process and to share in the benefits. The change in terminology, which now has us talking of third-world counties where formerly we referred to developing countries, is an indication of a fading optimism.

However, we must acknowledge that some remarkably rapid processes of economic growth have been occurring in some parts of the non-western world. In Indian and China, and in many parts of South East Asian, accelerating processes of industrialisation are underway; and already the west depends largely on the cheaper products of these economies.

There have been some notable exceptions to the optimistic view of economic development. Throughout the 1960's and 70's a group of demographers were urging that a necessary accompaniment to the economic development of the third world had to be an attempt to staunch the growth of population. (See Erlich and Erlich 1992). Others argued that the available supplies of mineral resources, of fuel and of foodstuffs posed strict and severe limits to growth. (See, for example, Meadows et al. 1972 and the sequel 1992)

In recent years, environmental scientists have been urging upon us the view that the planet is suffering from an inability to absorb the waste products and to repair the depredations of human activities. In contrast to the earlier view that the material resources posed limits to growth, the modern environmental movement sees that it is often the relative abundance of some of these resources that poses the more imminent threat. In this view, there are enough available resources to allow the human population to embark on the complete destruction of the global ecosystem. (See McMichael 1993)

Of course, for a meaningful analysis, we will have to deal with particular details instead of offering generalisations. Thus, for example, There is an abundance of coal and oil, sufficient to sustain the industrial development of India and China while adding massively to the burden of atmospheric CO_2. Also, the supplies of minerals, such as bauxite and iron ore, do not seem to be seriously threatened.

However, much of the world's cropland, which has contributed to a rapid growth in food production in the 20th century, is now prone to soil erosion and salination (see Postel 1999). Also, the fish in the seas are already grossly depleted in numbers and, if we are to credit current reports, they carry a heavy burden of industrial pollutants in their tissues, which threatens to make them inedible according to the standards of western consumers. The picture is a complicated one, and it is not a comforting one.

Some critics fear that the growth of the south East Asian economies cannot proceed along the present paths without creating insuperable environmental problems that sooner or later will bring the process to a halt. In most respects, these economies are simply mimicking the developments that have already occurred in the West. The inference is that it will not be possible for the majority of world's population to achieve the typical lifestyles and the material affluence of the citizens of the west.

Ecological Dynamics

We ought to digress briefly to reconsider the phenomenon of exponential growth in order to illustrate one of its consequences that even sophisticated analysts do not always apprehend clearly. We can do so by thinking of an old riddle that is traditionally posed to students embarking a course of population ecology. The riddle is follows. Suppose that there is a lake with some lily pads in it, and suppose that each lily pad replicates itself once a week. If it takes a year for the lake to be half covered with lily pads, how long will it take for the entire lake to be covered?

If one does not think too deeply, then one is liable to propose that it will take another year or so complete the coverage. Indeed, this would be the consequence of a linear growth. However, a moment's thought finds the true answer. The lake will be completely covered in one week's time. This is the consequence of the exponential growth of the coverage.

Some significant insights emerge from this seemingly trivial story. The story is a parable of the growth of biological populations, whether they be viruses or lily pads or plagues of locusts or hoards of human beings.

The essential feature of the story is the manner in which it highlights the potential for surprise. We can persist in thinking that a gradual expansion into a seemingly limitless environment can continue indefinitely, but, if there are finite limits, then these may be encountered very suddenly in a way that can catch us unawares. An improbable degree of foresight might be required even to envisage the limits.

The framework of academic economics is peculiarly ill equipped to cope with such realities. Its emphasis is upon equilibrium at the expense of ecological dynamics. Also, microeconomics continues to be dominated by the Law of Myopia, which is the principle of discounting, in other words. This serves to foreshorten the temporal horizons of the economist, which can become as limited as the commercial horizons of a businessman intent on maximising current profits.

The next thought that occurs to us concerns the likely consequences of meeting the limits. How will the shock of the sudden encounter be absorbed by the growing population? Will it, for example, lead to a widespread increase in the rates of mortality in the human population, as is often the case when swarming populations of birds, insects and other pests discover the carrying capacity of their environment. Will it, alternatively, lead to an orderly adaptation in the rate of growth and reproduction.

This is a leading question for demography. Can human populations be expected, in all circumstances to undergo the sorts of transitions that have led to the virtual stabilisation of the populations in many of the industrialised counties? Or will the burgeoning third-world populations be checked by widespread human disasters including famine and epidemic disease? If that should be the case, then could any of the human populations in the modern globalised world expect to escape such disasters?

The talk of linear and exponential growth and of their disparity should bring the doctrines of Thomas Malthus to the minds of economists. Economics has been described as the dismal science in consequence of the dire predictions Malthus.

Malthus contemplated the outcome of an unbridled growth of human populations proceeding at a geometric (i.e. exponential) rate when the means of substance increases only at an arithmetic (i.e. linear) rate. He envisaged that, inevitably, populations would be culled by famine, disease and warfare. The dismal nature of his predictions sprung from the fact that he believed that these were the only means by which the growth of population could be arrested. He did not foresee any effective role for human self restraint.

The doctrine was a nihilistic one. In the opinion of Malthus, it was better not to intervene with charitable works in an attempt to alleviate the misery of the rural

poor. By so doing, one would encourage them to increase their procreation, which would lead, inevitably, through increased numbers, to further misery.

There has been a widespread revulsion to the doctrines of Malthus amongst liberal thinkers and, through the economic successes of the industrialised western world, it seems that he has been proved wrong. Nevertheless, there is a growing suspicion that something akin to the Malthusian scenario is emerging in parts of the modern world.

The Beginnings of the Industrial Revolution

Once we recognise that the modern processes of economic growth cannot continue indefinitely in an environment of finite limits, we can see that they must have had an identifiable beginning and that they are heading toward an inevitable end.

The circumstances that have created our modern urbanised and industrialised world are recent. Most people are content to place their inception at the beginning of the industrial revolution, which, in the case of Britain, will take us back no further than the middle of the 18th century.

Nevertheless, it seems reasonable to reach back as far the middle of the 14th century when the human population suffered an unprecedented disaster. This was the Black Death pandemic that arrived in Europe in 1347. Over the next two years, the plague caused the deaths of as many as 30% of the European population. The processes of re-expansion that followed broke the mould of the mediaeval feudal system that had held society in thrall, and they engendered a new dynamism.

In Britain, the re-expansion had been completed by the Elizabethan times in middle of the 16th century, which, in the parlance of historians, constitutes the early modern period. It is not hard to trace the processes of social, technical and economic development that led from the late Tudor period to the beginning of the industrial revolution in the middle of the 18th century.

The industrial revolution began with a confluence of several mutually supporting developments. We tend to think primarily of the introduction of the factory system, which, at first, was mainly associated with textile manufacture. However, the revolution in manufacturing was sustained by numerous other contemporaneous developments.

The first of these supporting deveopments was a revolution in agriculture that saw the introduction of farming methods that relied upon crop rotation and which enhanced the essential processes of nitrogen fixation. That is to say, the fertility of the soil was greatly increased over wide areas of farmland. The agricultural revolution was necessary to sustain the increasing number of urban dwellers and non-agricultural labourers, not to mention the standing armies and the navy of the Napoleonic era.

The was also a revolution in metallurgy, which greatly increased the supplies of iron and steel for use in armaments and machinery and for tools and domestic

utensils. Eventually, a vastly expanded supply would be needed to satisfy the demands of railway construction, which arose in the middle of the 19th century and to satisfy the demands of the shipbuilding, towards the end of the century.

The next development to mention was that of mining, which provided the coal that became the basic source of energy. Coal and coke were greatly used in the production of iron. It was used in lime kilns, in potteries and in brick making. It was also available for domestic heating and for powering the stream engine, which became the prime mover of the industrial revolution.

The burning of coal replaced wood burning and the use of wind and running water as a source of energy. In effect, renewable energy resources were replaced by a depleteable one. Coal ceded its place as the primary source of energy only in the latter half of the 20th century. In the 1950's, the urban environment was still drenched in the sulphurous products of coal combustion; but a great change, which saw the replacement of coal by oil, was already underway.

In the early years of the industrial revolution, the manufacture of cotton thread and cotton cloth had depended upon the harnessing of the power of running water; but, by the 1800's, the coal-fired steam engine was in the ascendancy.

The steam engine, in the form of the so-called atmospheric engine, was first introduced into English mines as a means of pumping water from the workings. The first installation was by Thomas Newcomen in 1712; and the device was installed in a growing number of mines after 1750. However, such engines had a very low thermal efficiency, and they were not appropriate for powering rotating machinery.

We have to wait until 1775 to see a significant innovation in steam engine technology. This was when James Watt patented the separate condenser, which resulted in a major improvement in efficiency. A later invention of Watt was a double-acting engine in which the piston, which was initially located in a vertical cylinder, was driven by steam both on the upstroke and the down stroke. The cycle of innovations was completed by Watt's famous centrifugal governor that allowed the engine to maintain constant speed with varying loads.

With this final innovation, the steam engine could be deployed on a wide scale to power rotating machinery. The combination of James Watt's engineering skills and Matthew Bolton's entepreneurship had resulted, by 1800, in the manufacture of no less than 500 rotary steam engines.

Industry, Trade and Empire

Industrialisation was also accompanied by the growth of worldwide merchant trade, and by the growth of European colonialism. The Spanish and the Portuguese had pioneered colonialism. Later, it was pursued by the Dutch, the British, the French and, and thereafter by the Americans in a disguised form of neo-colonialism. Colonialism was responsible for spreading the effects of the European industrial revolution to the rest of the world.

By the middle of the 19th century, Spain and the Portugal no longer exercised effective control over their colonies. Other European nations played lesser roles but, at the time of the Congress of Berlin in 1878, it seemed that virtually every European nation was keen to participate in the enterprise. The Congress of Berlin was a gathering of European nations that sought to define their respective spheres of colonial influence, and it initiated the so-called "Scramble for Africa".

Trade and the colonialism have been jointly responsible for spreading the effects of industrialisation across the globe, so that, for the past 200 years, events in Europe and America have had worldwide consequences.

The Demography of the Industrial Revolution

The middle of the 18th century saw a marked increase in the rate of growth of the British population, which was echoed, with various delays, in other European countries. In Britain, this growth seems to have been the consequence of a curious hiatus in infectious disease, both in the rural and in the urban environments.

After 1666, there was no recurrence of the plague in Britain. Its last occurrence anywhere in Europe was in 1720 in Marseilles. The warfare that had afflicted Europe in the 17th century was temporarily in abeyance. The great 30 years war was ended by 1648. One of the results of the population growth that occurred in Britain in this time of relative peace and prosperity was to generate the reserve army of rural labourers that was to supply workers to the industrial cities that began their rapid growth toward the end of the 18th century

The conditions of the cites of the industrial revolution did not result in the widespread epidemic disease that might be expected if we were to take the late Mediaeval European cities as comparable examples.

This is the first time that the city of London, for example, became a net producer rather than a consumer of people. However, it was much later, toward the end of the 19th century, that the urban disease of typhoid was eradicated from the metropolis and, it was only by the middle of the 20th century that the other great killer of the industrial revolution, which was tuberculosis, was fully eradicated.

The *Essay on Population* by Malthus, which dates from 1798, may be seen as a response to the problems created by Britain's burgeoning rural population. The ties to the land had been weakened by the enclosure movement, which was dispossessing the peasants of the common land from which they had traditionally derived a significant part of their subsistence.

The enclosure movement was given a further impetus by the agricultural boom that accompanied the Napoleonic wars. Great tracts of cultivable land were enclosed and given over to wheat which, in the absence of significant imports, was needed to satisfy the demands of Britain's war economy and of its growing industrial army.

We can estimate that the population of Britain had reached some 10 million by 1750. By 1800, it had jumped to 16 million and by 1900 to 45 million. It is now some 64 million. Its absolute rate of growth may have been greatest at the beginning of the 20th century, but its proportional rate of grow had already slowed. Here, we must bear in mind the nature of exponential growth, which is constant proportional growth. Similar patters are found across Europe, but Britain has experienced one of the most rapid growths of population of the continent.

19th Century Developments in Industry and Trade

By the beginning of the 19th century, the process of industrialisation was well underway in Britain and in other European countries. Many of the effects of the modern world were already in place by 1800. A threshold had been crossed. Mechanical invention and the application of science to technology, which is a hallmark of the modern world, had already become a feature of industry.

The Napoleonic wars gave a further stimulus to Britain's manufacturing. The naval dockyards at Portsmouth, Devonport and Chatham became increasingly like modern production lines. There was a huge demand for timber. Old saw pits, which had relied upon the exhausting labour of two highly skilled sawyers, were replaced by steam powered machines. Machinery was invented for the spinning of ropes and for the manufacture of blocks for pulleys. Cannons were bored to an increasing precision in a manner that had a marked effect upon the manufacture of the steam engines.

The ensuing years of the 19th century were to see most of the remaining elements added to the industrial economy. Much of the first half of the century was devoted to the exploitation of the technologies that were already established by 1800. The massive and widespread application of these technologies in Britain and throughout Europe was the significant development.

Two important new technologies of this period, which developed together, were the railways and the electric telegraph. The first practical electric telegraph began operating in 1837, which is when the Morse code was first used. By 1867 there was a working transatlantic telegraph link. The telegraph was the 19th century Internet, and it eventually fell into abeyance in the late 1960's.

The first passenger-carrying railway with steam locomotives was the Liverpool Manchester Railway, which opened in 1830. The construction of rail networks throughout Europe proceeded rapidly thereafter. The Union Pacific railway that traversed the United States was completed in 1869; and, at that stage, railways were being established throughout the world. Latin America and India acquired railway systems, and in the 1890's the construction of railways was begin in Africa. The first Indian Railway, which was between Bombay and Thana, opened in 1853. By 1910 there were more than 32,000 miles of lines in what are now India, Parkistan and Bangladesh

The importance of the advent of the railway in the Indian subcontinent cannot be overestimated. It had a profound effect on the demography of the subcontinent. Hitherto, famine, which was endemic in India, was an affliction against

which there was no effective recourse. With a railway system in place, there was the possibility of rapidly transporting grain and other foodstuffs to the afflicted areas. The most vulnerable elements of the population, who were the children and the elderly, who, previously, would have succumbed to famine, now had a chance of surviving. The consequent reduction in infant mortality, which occurred towards the end of the 19th century, was the primary cause of a massive and rapid increase in the India population.

It is relevant in this connection consider the fate of the Irish in 1847 when the great potato famine struck. There is still animosity arising from this event. In particular, it is maintained that, instead of distributing foodstuff in order to alleviate the famine, the British administration and the Anglo Irish landlords garnered the available supplies of grains in storehouses from which much of it was exported. It can be said, in partial exoneration, that there was no available system of transport that would have enabled the foodstuffs to be distributed to the starving population. The railways were yet to come to Ireland.

The effect upon the demography of Ireland is still visible. The country has not regained the population of the pre-famine days. On the eve of the famine, it has reached its maximum of 8.5 million. Nowadays, it numbers some 5 million. A massive emigration to the United States and to some of the British colonies, to Australia in particular, was responsible for the reduction in numbers, albeit that the death from starvation of some 0.75 million was an immediate cause.

It is interesting to observe that a marked change in the nature of British colonialism in India occurred in the middle of the 19th century. The basis of the British Indian Raj had been established earlier at the end of the 18th century under such military administrators as the viceroy Richard Wellesely and his brother Arthur Wellesely, who was to become the Duke of Wellington. One by one, the Indian prices became the clients of the British; and those who opposed them were defeated by alliances formed by the British with others. The historic watershed was the Indian Mutiny of 1857. Thereafter, Britain assumed complete military control and the number of British present in India were greatly increased.

These developments owed much to the advent of steam navigation. At first, there were steam-assisted sailing ships and, eventually, there were ocean liners and cargo ships. Regular sailings carried civilian and military personnel back and forth between Britain and India. The cargo ships carried the material for the construction of the Indian railways.

The Turn of the Century

Towards the end of the 19th century, we see the arrival a raft of new technologies, which are set to have major effects in the 20th century. Amongst these is the emergence of electrical power as a means of lighting, to replace gas, and as the motive force for light industry. For the advent of the domestic electrical appliances, we have to wait until the early years of the 20th century.

The automobile also arrived at the end or the century together with the internal combustion engine; and, in 1904, the Wright brothers of Dayton Ohio achieved the first powered flight, also by virtue of the internal combustion engine. The oil that provided the petroleum was extracted both in the United States and in the region of the Transcaucasus (i.e. Georgia, Armenia and Azerbaijan). It was well into the 20th century that the Middle Eastern oil began to be exploited or a wide scale, at first in Iran and Iraq and later in the Gulf of Arabia.

A highly significant development of the late 19th century and the early 20th was the emergence of the chemicals industry. It was Germany that led the way with such inventions as the Harber process, by which ammonia NH_3 is manufactured. Amongst the products of the chemical fixation of nitrogen were the nitrate fertilisers, which are universal in modern agriculture, and the nitrate explosives, which were employed with devastating effect in the First World War.

The 20th Century

So far, we have given an account of roughly 150 years of industrialisation and technological innovation. At this point, most of the 20th century lies ahead of us. Its history is more accessible than that of the preceding 150 years, partly because we are surrounded by its consequences. However, there are some crucial factors that can escape our immediate attention.

You are invited to consider the items that are included on the list that is to be found at the end of this essay, and to add to them. There are two items on the list that are liable to strike us less forcibly that they should.

The first of these concerns the era of Hyro engineering that spanned the 1920 and 1930's and which has be responsible for the present circumstances of agricultural production in much of the developing world. The great irrigation schemes of the Indus River, which reached fruition in the 1930's, have been responsible for sustaining the productivity of much of Indian agriculture. They were the basis of the so-called green revolution that gave cause for great optimism in the 1960's and 1970's.

The benefits of these schemes have now been reaped, and the disbenefits are beginning to give cause for concern. All such schemes carry with them the danger of prejudicing the long-tem fertility of the soil. The soil-salination that can accompany irrigation is effectively irreversible, and it is now threatening the productivity or Indian agriculture.

A dramatic example of the destruction of fertility in consequence of a misguided irrigation project is provided by the Soviet hydro engineering project that diverted the waters that flowed into the inland Aral Sea, which has the republics of Kazakhstan and Uzbekisnitan on its shores. The object was to create area of farmland to rival the American Midwest, where wheat and cotton could be grown in abundance.

The effect has been to create a wasteland in which dust and the toxic residues of chemical fertilisers swirl over desiccated deserts. The Aral Sea has shrunk

to a fraction of its original area. The hydro engineering projects on which the Chinese have embarked may eventually have similar consequences.

The second topic that deserves our attention is denoted by the title antibiotics, which stands for the wider effects of modern medicine upon the mortality of the world's populations. The global population explosion is attributable, in large measure, to the effect of modern medicine in the third world. In the industrialised western world, the effects of improvement in sanitation and hygiene were experienced long before the effects of the innovations in medical science. They were largely responsible for the reductions in infant mortality that gave rise to the rapid increase in population.

These increases were staunched by the gradual changes in behaviour and social attitudes that constitute a so-called demographic transition. The term denotes the processes by which the birth rate is eventually reduced to conform to the lowered rate of mortality.

In third-world countries, the reduction of the rate of infant mortality has often been accomplished by western medicine without the accompaniment of significant improvements sanitation and hygiene. The agency has been the resort to inoculations and the deployment of antibiotics, which became available on a large scale only after the Second World War. The effect has been dramatic, and it has occurred rapidly. The reduction in infant mortality has not been accompanied by a commensurate reduction in the birth rate; and the consequence has been a population explosion.

Whereas the population continues to expand in consequence of the disparity between birth rates and death rates, the efficiency of antibiotics is set to decline. The limits of many resources that are necessary to ensure the quality of life are being encountered already. The likely scenario is that many of the resources will become depleted in the next century, partly in consequence of their over exploitation and partly in consequence of the effect of global warming

A rise in the level of the sea by one meter, which is a likely consequence of the warming, threatens to inundate 30 percent of the world's fertile crop land, which is to be found in low lying river valleys in river deltas and in estuaries. These prospects cannot be contemplated with equanimity.

A Check List of Events and Circumstances

The 18th Century
- The Factory System
- The Agrarian Revolution
- The Revolution in Metallurgy
- The Steam Engine

The 19th Century
- 1804 The Battle of Trafalgar
- The Railways
- Demographic Developments
- Trade and Empire
- 1854 The Crimean War
- Gas Lighting
- 1869 American Transcontinental Railway
- The Electric Telegraph
- Mechanisation of Agriculture
- Electrical Lighting
- Indian African and Latin American Railways
- The Steamship and the Empire

The 20th Century
- The Petrochemical Industry
- The Automobile
- 1904 The Wright Brothers
- The Radio
- Aviation
- Irrigation and Dam Building
- Antibiotics
- Global Population Explosion
- The Television
- 1945 Hiroshima
- The Nuclear Bomb
- Air Travel
- Nuclear Power
- The Population Explosion
- The Computer Revolution
- Aids
- The Internet

The 21st Century
- Climate Change
- Agricultural Crisis
- Alternative Energy Sources
- The Declining Efficacy of Antibiotics