Chapter 2: The Logic of the Malthusian Economy

"No arts; no letters; no society; and which is worst of all, continual
fear, and danger of violent death: and the life of man, solitary,
poor, nasty, brutish and short." Hobbes, <u>Leviathan</u>, Book I, ch. 13
(1651).

Introduction

The vast majority of human societies, from the original foragers of the African savannah

down through settled agrarian societies until about 1800, had an economic life that was shaped

and governed by one simple fact: birth rates had to equal death rates on average. Since this same

logic governs all animal species, before 1800 in the "natural" economy the economic laws for

humans were the same as for all animal species.

It is common to assume that the huge changes in the technology available to people, and

in the organizational complexity of societies, between our ancestors of the savannah and

Industrial Revolution England, must have improved the human condition even before modern

economic growth began. But in this chapter I show that the logic of this natural economy

implies that the material standard of living for the average person in the agrarian economies of

1800 was if anything worse than for our remote ancestors. Thomas Hobbes, in the quote above,

was profoundly wrong to believe that in the state of nature man was any worse off than in

England in 1651.

Since Thomas Malthus in 1798 was the first to at least partially grasp how pre-industrial

economic systems had to function, we refer to the model developed below for pre-industrial

societies as the Malthusian model. This starts from the insight that the biological capacity of

women to produce offspring is much greater than the number of births required to reproduce the

population. If fertility is unrestricted it is possible for women sexually active throughout their

reproductive lives to have twelve or more children.[1] Social institutions regulating the age of

marriage, the percentage of women marrying, extramarital fertility, and contraceptive practices

will determine the actual numbers of children per women. In modern societies these institutions

and practices vary greatly so we observe great variation in the number of births per women.

Thus as table 1 shows the number of births per woman in 2000 ranged from a low of 1.15 in

Spain to a high of 8.0 in Niger. This means that in Spain each women of the current generation

is being replaced by at maximum 0.575 women of the next generation (assuming all girls survive

to adulthood). In Niger in contrast if all daughters were to survive to adulthood there would be 4

women in the next generation for every woman now.

Only where women happen on average to have two children who survive to adulthood

will population be stable in the long run. Even small deviations from this number will cause

rapid increases or decreases in population. Thus table 1 also shows the population projected for

2050, if all children born in these various societies survive to adulthood.[2] If all these children

survive countries are on a knife edge between explosive population growth and catastrophic

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[1]We know this from observations of the fertility levels of Hutterites in the 1920s to 1950s. The Hutterites were an Anabaptist sect settled in the upper Great Plains of the USA modern religious groups who married early and did not practice birth control. Hutterite women married from 15 to 50 had 12.5 children on average. Both my grandmothers, who were Irish Catholics who married at the unusually early age for this community of 16, had large families: one 12 and the other 13 children.

[2]This projection also assumes, incorrectly, that current fertility patterns had prevailed across previous generations.

population decline. In fifty years there would be only 22 million Italians compared to 57.5 million now, but 113 million Saudi Arabians compared to 22.1 million now.[3]

Despite this potential for explosive growth pre-industrial populations grew remarkably slowly in the long run. The average growth rate of world population from 10,000 BC to 1,800 AD was 0.05% per year. At this rate a community of 100 people on average gained a person once in every 20 years. The typical women before 1800 thus had 2.02 children who survived to reproductive age. As an extreme case the population of Egypt, for example, is estimated at between four and five million circa 1,000 BC.   The population in in Greek and Roman Egypt 1,000 years later is estimated at this same four to five million. The first modern census in 1848 suggests a population of about 4.5 million.   Thus over a period of 2,850 years the growth rate of population despite some swings up and down was to a very close approximation zero, and women on average had two surviving children.[4] Yet Roger Bagnall and Bruce Frier estimate that in Roman Egypt in the first three centuries AD the average woman gave birth to six children.[5] The long run stability of population sizes was also found in pre-industrial Europe. From 1340 to 1680 the population of the major European countries actually fell slightly, as table 2 shows, though there had been significant growth in the years 1100 to 1340. Assuming a generation length of 25 years the average number of surviving children per woman from 1340 to 1680 ranged from 1.90 in the Netherlands to 1.99 in France. All these countries were close to the stable population level of two surviving children per woman.

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[3] This is assuming, incorrectly, that the current fertility rates have prevailed over the last 70 years in these societies.

[4]McEvedy and Jones (1978), pp. 228-9, Bagnall and Frier (1994), pp. 54-56.

[5] Bagnall and Frier (1994), p. ---.

The Malthusian Equilibrium

The simple Malthusian model of how pre-industrial society functioned supplies an economic mechanism to explain the population stability of pre-industrial economies. In its simplest version there are just three assumptions:

1. The **BIRTH RATE** is a socially determined constant, independent of material living standards.

2. The **DEATH RATE** declines as living standards increase.

3. **MATERIAL LIVING STANDARDS** decline as population increases.

The birth rate is just the number of births per year per head of the population, normally quoted by demographers as the number of births per year per thousand people in a population. At maximum observed fertility levels this would be about 50 or 60. As we saw the birth rate can vary dramatically across societies. Table 3 shows the modern range. In Italy, one of the countries with the lowest birth rate in the world, there are now only 8.8 births per thousand people per year. In very poor countries birth rates are in the order of 40-50 births per thousand. Thus in the area of highest birth rates which is Central Africa some countries have birth rates which exceed 50 per thousand: Niger 55.2, Somalia 52.1, Uganda 50.7.

The death rate is again just the number of deaths per head of the population, typically quoted as the number of deaths per thousand of population. In a stable population the death rate

is the inverse of life expectancy at birth.[6] Thus if life expectancy is 75 years the death rate will

be 13.3 per thousand. If life expectancy is 30 years the death rate will be 33.3 per thousand.

Because of growing populations, which have fewer old people, many countries in the modern

world have death rates below 10 per thousand, as table 3 demonstates.

The growth rate of population is simply the birth rate minus the death rate. Thus in a

stable population the birth rate equals the death rate by definition, so life expectancy can be

equivalently calculated as the inverse of the birth rate. In a stable population a birthrate of 50

per thousand of population implies a life expectancy of 20 at birth. Thus if pre-industrial

populations typically displayed the fertility levels of the modern Niger, life expectancy at birth

would have to have been less than 20.

In the modern world populations in general are not stable but changing rapidly. Table 3

shows for a range of countries birth rates, death rates and the consequent rates of population

growth from natural increase, and also the rates including migration. As can be seen Niger in

2000 had a growth rate of population from natural increase and migration of 3.62 percent, so that

the current population of 10.7 million is projected to grow to 65.6 million by 2050, six times the

current population. For Saudi Arabia the projected population is 95.4 million, over four times

the current population.

Material living standards are just the average amount of goods (food, alcohol, shelter,

clothing, heat, and light) and services (religious ceremonies, barbers, servants) that people in a

society consume. Where new goods are introduced over time, such as newspapers, Wedgewood

fine porcelain, and vacations at the seaside, it can be very tricky to compare societies in terms of

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[6]If D is the death rate then $D = 1/e_0$.

the purchasing power of their real wages. But for most of human history, and for all societies

before 1800, the bulk of material consumption has been food, shelter and clothing material living

standards can be measured with much more accuracy.   In societies economically sophisticated

enough to have a labor market, material living standards for the bulk of the population will be

given by the purchasing power of wages.

Figure 1 shows the first two assumptions of the simple Malthusian model in graphical

form. The birth and death rates are plotted on the vertical axis, material income per capita, y, on

the horizontal axis. As can be seen the first two assumptions of the simple Malthusian Model

imply that there is only one level of real incomes at which the birth rate equals the death rate,

which we denote as y*. At material incomes above y* the birth rate exceeds the death rate and

the population is growing. At material incomes below y* the death rate exceeds the birth rate

and the population is decreasing. Thus y* I call the "subsistence income" of the society: it is the

income at which the population barely subsists, in the sense of just reproducing itself.   Notice

that this subsistence income is determined without any reference to the production technology of

the society. It depends only on the factors which determine the birth rate and those that

determine the death rate. Once we know these we can determine the subsistence income, and the

life expectancy.

The terminology "subsistence income" can lead to the confused notion that in a

Malthusian economy people are all living on the brink of starvation. In fact in almost all

Malthusian economies the subsistence income will be considerably above the income that is

required to allow the population to feed itself from day to day. And differences in the location of

the mortality and fertility schedules can generate very different subsistence incomes. Thus both

1400 and 1650 were periods of population stability in England, and hence periods where by

definition the income was at the subsistence level. But the wage of the poorest workers,

unskilled agricultural laborers, was equivalent to about nine lbs. of wheat per day in 1650,

compared to 18 lbs. in 1400. Even the 1650 unskilled wage was well above the biological

minimum required to keep workers alive. A diet of about two lbs of wheat per day would keep a

laborer alive and fit for work (it would supply about 2,400 kcal per day). Thus pre-industrial

England, while it was a subsistence economy, was not a starvation level economy. Indeed we

shall see below that there are some indications that it was at times a wealthy economy, even by

the standards of many modern societies.

Figure 2 illustrates the third assumption. The figure has on the vertical axis the

population, N, and on the horizontal axis the material income. The diagram shows a curve

connecting population and material incomes. For reasons that will be given below, I call this

curve the "technology schedule." As population increases the material income per person by

assumption declines, so the curve slopes downwards. The justification for this assumption is the

so called the "Law of Diminishing Returns."[7] Any production system employs a variety of

inputs, the principle ones being land, labor and capital. The Law of Diminishing Returns holds

that if one of the inputs to production is held fixed, then increasing the use of other inputs will

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[7]Since the Classical Economists who derived the key insights of the Malthusian Model had
not formulated the marginal principle they would not have expressed the theory in this way, but
their view that the means of subsistence would necessarily expand more slowly than population
until the wage fell to the susbsistence wage contains informally the essence of our third
assumption here.

increase output, but by smaller and smaller increments. That is, the output per unit of the other

factors will decline as their use in production is expanded, as long as one factor remains fixed.

Since one important factor of production, land, is always in fixed supply in pre-industrial

economies, the Law of Diminishing Returns implies that average output per worker will fall as

the labor supply increases as long as the techology is static. Thus the average amount of material

consumption available per person has to fall with increases in population. To see why this will

happen consider a peasant farmer with 50 acres of land. If he alone cultivates the land then he

will get the greatest output by using low intensity cultivation methods - keeping cattle or sheep

which are grazed for meat. With the labor of another person milk cows could be kept also,

producing a higher output.   With another person the land could be cultivated as arable, growing

crops of grain, again increasing output. Arable requires much more labor input per acre for

plowing, sowing, harvesting, threshing and manuring. But arable also yields a greater value of

output per acre. With even more people the land could be cultivated as even more intensive

garden ground, growing vegetables and roots, increasing output yet further.   This means that for

any given piece of land there is the relationship, shown in figure 3 between the amount of labor

applied and the value of output. The increase in the value of output from adding each person is

the marginal product of that person, which equals the wage in market economies. As can be seen

the marginal product declines as more people are added. In consequence average output per

person falls as the population rises.

Figure 4 puts figures 1 and 2 together to show how an equilibrium birth rate, death rate,

population level and real income is arrived at in the long run in a pre-industrial economy.

Suppose we start at an arbitrary initial population N_0 in the diagram. This will imply an initial

income y_0. The income will in turn imply particular birth and death rates. In figure 4 these have been drawn so that the birth rate exceeds the death rate, and y_0 exceeds y*. In this case population will start to grow. As it grows the income will fall. As long as the income exceeds y* the population continues to grow, and the income to fall, until y equals y* and N equals N*, at which point the population is stable. Suppose that instead the initial population had been so large that the income was below y*. Then the death rate would exceed the birth rate and population would fall. This would push up the income rate. The process would continue until again y again equals y* and N equals N*. Thus wherever population starts from in this society it always ends up at N*, with the income at y*. We can also see in figure 4 that the sole determinants of the long-run material income y* are the birth and death schedules. Knowing just these we can determine y*. The position of the curve relating wages and population serves to determine only what population corresponds to this long-run wage

Because I want to show that the same economic model applies to all human societies before 1800, even those which had no labor market, and also to animal societies, I have developed the model in terms of income per person. Classical Economists, however, writing about conditions in England circa 1800 developed their thinking in terms of the wages of unskilled workers. Thus in 1817, David Ricardo, using similar logic to that above argued that real wages (as opposed to income per person which includes land rents and returns on capital) must always eventually return to the subsistence level.[8] Ricardo's proposition later became known as the **Iron Law of Wages**. Classical Economics thus denied the possibility for other than transitory progress in material living standards.

Changes in the Birth Rate, Death Rate and "Technology" Schedules

Suppose that the birth rate schedule increased from B_0 to B_1 as in figure 5. What happens to the death rate, material incomes, and the population? In the short run the birth rate now exceeds the death rate. But this causes population growth which drives down the real income, increasing the death rate until $D(y) = B_1$. At the new equilibrium the death rate has risen to equal the new birth rate, the real income is lower, and population is greater. Thus any increase in birth rates in the Malthusian world drives down real incomes, and conversely anything which limits birth rates drives up real incomes. Similarly any increase in birth rates drives down life expectancy at birth. Pre-industrial society could thus raise both material living standards and life expectancy by limiting births. Since life expectancy at birth in a stable population is also just the inverse of the birth rate another important component of material living standards is solely determined by the birth rate. As long as this remained high life expectancy at birth had to be low.

Again if the death rate schedule moves up, as in figure 6, so that at each income there is a higher death rate, then at the current income deaths exceed births so that population falls. This drives up the real income until the death rate is driven down to the old birth rate. At the new equilibrium the death rate has fallen to the fixed birth rate, the income is higher, and population is lower. An increase in the death rate schedule, given a fixed birth rate, increases real incomes but in the long run has no effect on the annual death rate, or on life expectancy at birth.

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[8] McCulloch (1881), pp. 50-58.

The Malthusian world thus exhibits an almost counterintuitive logic. Anything that raised the death rate schedule, that is the death rate at a given income, such as war, disorder, disease, or poor sanitary practices, or abandoning breast feeding, increased material living standards without changing life expectancy at birth. Anything that reduced the death rate schedule, such as advances in medical technology, or better public sanitation, or public provision for harvest failures, or peace, reduced material living standards without any gain in life expectancy at birth.

While the real income was determined from the birth and death schedules, the population size depended on the schedule linking population and real incomes. Above I labelled this the "technology" schedule, because in general, as we shall see the major cause of changes in this schedule has been technological advances. But other things could shift this schedule – a larger capital stock, improvements in the terms of change, climate improvements, and a more productive organization of the economy.

Figure 7 shows a switch from an inferior technology, represented by curve T_0, to a superior technology, represented by curve T_1. Since population can only change slowly, the short run effect of a technological improvement is an increase in real incomes. The increase in real incomes reduces the death rate, so that now births exceed deaths and population begins to grow. The growth of population only ends when the income has returned to the subsistence level, y^*. At this equilibrium the only effect of the technological change has been to increase the population supported. There has been no lasting change in the living standards of the average person. The path of adjustment to a one time improvement in technology is shown if figure 8.

The Malthusian Model and Economic Growth

Before 1800 there was very significant improvement in production technologies, though these improvements happened at a very slow rate. The technology of England in 1800, which included cheap iron and steel, coal for energy, canals to transport goods, firearms, and sophisticated sailing ships, was hugely advanced on the technology of hunter gatherers in the Neolithic before the development of settled agriculture. But the rate of improvement of technology was always slow relative to the world after 1800. Figure 9, for example, shows the average yield of wheat on a number of farms in England from 1211 to 1453. Interestingly the yields show absolutely no sign of any gains over this long interval of nearly 250 years. Before 1800 the rate of technological advance in any economy was so low that populations were always condemmed to return to the Malthusian Equilibrium.

This was still the historical context in England in the years 1798-1817 when Thomas Malthus (1766-1834) and David Ricardo (1772-1823) were developing what became known as Classical Economics, with its key doctrine of the subsistence wage. They did not assume, as we do, that technical progress is inevitable and continuous, but instead regarded it as sporadic and accidental. Even in the circumstances of England in 1798-1817, when the economy was well into the period we now dub the Industrial Revolution, this assumption was not just reasonable, but indeed compelling in the light of history. The new technologies associated with the Industrial Revolution begun appearing in the 1760s, but from 1770 to 1817 real wages were flat. We shall see that sustained real wage gains started only in the 1820s, and that much of these gains were a product not of English technological advance, but of events beyond England, and of a change in tax policy. Indeed one of the great social concerns of the years 1780-1834 in

England was the problem of the rising burden on property owners of payments to support the poor under the Poor Law.

Thus Malthus and Ricardo predicted that as long as fertility behavior was unchanged, economic growth could not in the long run improve the human condition. All that growth would produce would be a larger population living at the subsistence income. China, for Malthus, was the embodiment of the Malthusian economy. Though the Chinese had made great advances in draining and flood control, and had achieved high levels of output per acre from their agriculture, they still had very low material living standards because of the dense population. Thus he writes of China,

> If the accounts we have of it are to be trusted, the lower classes of people are in
> the habit of living almost upon the smallest possible quantity of food and are glad
> to get any putrid offals that European labourers would rather starve than eat.[9]

Malthus's Essay appeared in 1798. He apparently wrote it as a response to the views of his father, Daniel, who was a follower of the Utopian writers William Godwin and the Marquis de Condorcet. These writers argued that the "misery, unhappiness and vice" so common in the world was not the result of an unalterable human nature, but was the product of government. Malthus wanted to establish that poverty was not the product of institutions, and that changes in these institutions would not improve the human lot.[10] As we see, in a world of slow technological advance, his case is compelling.

Another implication of the Malthusian model, which helped give Classical economics its seemingly conservative stance, was that any move to redistribute income to the poor (who then

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[9] Malthus, Essay, p. 115. The situation in China may have been very different than Malthus viewed it however, as we shall see.

in England were mainly the class of unskilled farm workers) would result only in more poor in the long run, employed at even lower wages. As Ricardo noted in 1817,

> The clear and direct tendency of the poor laws is in direct opposition to these obvious principles: it is not, as the legislature benevolently intended, to amend the condition of the poor, but to deteriorate the condition of both poor and rich (McCulloch, 1881, p. 58).

Any growth in the wages of the laboring class above subsistence would simply result in an increase in the laboring population, putting downward pressure on market wages. In the end the subsistence wage would prevail.[11] Conversely taxing the poor would not hurt them in the long run. Thus though before 1800 most taxation by European countries was for military purposes, and much of it was raised from the poor in the form of taxes on commodities, this should have had no long term effect on their welfare. The initial fall in living standards caused by the imposition of new taxes would increase the death rate, and so reduce the population until the post-tax wage had been restored to the level of the old pre-tax wage.

Work Hours in the Malthusian Economy

The considerations above would imply just that material living conditions were no better in 1800 than on the Savannah, assuming no change in fertility behavior. But there were other

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[10] See Harry Landreth and David Colander, History of Economic Thought, pp. 100-103.

[11] Thus Classical Economics was very influential in creating the draconian reforms of poor relief in England legislated in 1834. The most influential member of the Poor Law Commission set up to examine the workings of the old poor law was Nassau Senior, Professor of Political Economy at Oxford University. Senior wrote the whole of the report of the commission, organized the inquiry that produced the report, and then lobbied vigorously to get Parliament to implement the proposals.

changes between forager societies and agrarian societies in 1800 that would imply an actual decline in living standards.

So far I have assumed work hours per person were the same in all Malthusian economies, so that labor input was proportionate to population. But there has been a long debate in anthropology about how much work people had to do to achieve the subsistence wage in various societies.[12] The earlier anthropological tradition assumed that hunter gatherers lead hard lives of constant struggle to eke out a living. The Neolithic agricultural revolution, by increasing labor productivity, reduced the time needed to attain subsistence, and allowed time for leisure, craft production, religious ceremonies and other cultural expressions.

However, with the innovation of systematic time allocation studies of hunter-gatherer and shifting cultivation groups in the 1960s, it has been shown that labor inputs devoted to subsistence in these societies are surprisingly small, and indeed total work time may well be less than in settled agrarian societies. Thus table 4 shows the rather modest number of estimates of the total work input of males per day in modern societies where forgaging or hunting were still large components of activity. For these societies, where people supported themselves typically through a mix of subsistence cultivation, often through slash and burn techniques, and hunting, fishing and gathering, total hours of work by males, including food preparation and child care, averaged just 5.5 hours a day, or 2,000 hours per year. To put this in context time studies that include housework, house-repair, child care, shopping and commuting suggest that modern American males, for example, engage in nearly 3,200 hours of labor per year (8.7 hours per

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[12] See, for example, Gross (1984).

day).[13] Thus males in these subsistence societies consume about 1,200 hours more leisure per

year than in those in affluent modern America.

The evidence is that labor inputs for adult males increased to modern levels long before

the end of the pre-industrial era. Thus by 1800 in England both agricultural workers and

building workers in towns seem to have worked 10-11 hours per day for about 300 days per year,

counting just their paid labor. For building workers we get evidence on the length of the typical

work day from the fact that workers charged for their services both by the hour and by the day.

The ratio of daily to hourly wages suggests the typical hours per day. Table 5 shows this

evidence, which suggests that at the dawn of the modern era in 1800 building workers were

putting in an 11 hour day in England. Since the work year was 300 days or more, average daily

hours of paid labor for these workers over the whole year would be nine per day, nearly 60%

greater than all labor inputs per day in modern forager-farmer communities. Agricultural

workers seem to have had similarly long numbers of days per year. Joachim Voth in an

interesting study used summaries of witness statements in criminal trials which often contain

statements of what the witness was doing to estimate annual work hours in England in 1760,

1800 and 1830. His results for London, where the information is most complete, are shown in

table 5. They suggest the average adult male Londoner in 1800 was employed 9.1 hours per day

on average. These results and are quite consistent with the evidence on the length of the work

day for building workers.

Suppose a Malthusian economy where workers work 2,000 hours per year experiences an

"industrious revolution" which increases labor inputs to the 3,000 hours per year typical of

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[13] Stafford and Duncan (1977), quoted in Minge-Klevana (1981).

English workers in the Industrial Revolution period. What is the long run effect of this on living standards? Figure 8, showing the effects of a technological advance in the Malthusian era actually covers this situation also. For the higher labor inputs would correspond to higher annual material output (which we take to be *y* in the figure), and thus a short run situation where births exceeded deaths, and hence population grew. Eventually with enough population growth the economy would again attain equilibrium, with the same annual real income as before, but workers now laboring 3,000 hours per year for this annual wage as opposed to the previous 2,000 hours. Indeed a community which had cultural norms which prevented people from working more than 2,000 hours per year would be better off than one where people were allowed to work 3,000 hours.

Thus if anthropologists are correct about the low labor inputs of hunter-gatherer societies then while we would expect material living standards to be the same between 10,000 BC and 1800 AD, real living conditions probably declined with the arrival of settled agriculture because of the longer work hours of these societies. The Neolithic agricultural revolution did not bring more leisure, it brought more work for no greater material reward.

More Complicated Malthusian Models

An issue that has exercised historical demographers is whether the birth rate in pre-industrial Europe was "self-regulating." What they mean by this is shown in figure 10. This shows the birth and death schedules of a simplified Malthusian model, as well as a modified birth schedule, which slopes upwards with material incomes. In the modified Malthusian model

it is assumed that in good times people marry earlier, and more marry, so that fertility increases, whereas in bad times fewer marry, and they marry later so that fertility declines.

It should be clear that it does not change the basic equilibrium of the model if the birth schedule slopes up. What does change is the mechanism and the speed with which the society gets back to equilibrium if some event pushes it away. In the simple Malthusian model, all the adjustment is done through changes in mortality. In the modified model changes in fertility play a role. If the population gets so high that material income is below y* in the simple Malthusian model people have to die to get the population back to equilibrium. In the modified model population can decline in part simply through the mechanism of reduced births.

What causes much more potential complications is a birth schedule that declines with material incomes. Suppose that as real incomes go up one of the automatic responses of people is to desire fewer children. Table 1 which shows real income per person alongside fertility seems to indicate that high incomes are linked to low fertility. With a birth rate that declines with real incomes the model could have multiple crossings between the birth rate and death rate schedules. At those places where the birth rate schedule was declining more steeply than the death rate schedule the equilibrium would be unstable. Figure 11 gives a declining birth rate schedule that twice intersects the death rate schedule. The intersection at the lower real income, y_0, is a stable equilibrium. If real incomes deviate from this level by a modest amount in either direction then the population automatically adjusts in such a way as to push incomes back towards y_0. But the second higher income equilibrium at y_1 is unstable. If real incomes drop below this level by any amount then population starts to grow, leading real incomes all the way down to the stable equilibrium at y_0. Conversely if they increase at all above y_0 then deaths will

exceed births and real incomes continue to grow indefinitely. The population will fall eventually to zero.

In this case there is thus a "Malthusian Trap" in the pre-industrial economy. A society can be stuck in the subsistence income equilibrium unless some jolt such as acquiring extra land, experiencing a much higher death rate, or experiencing faster technological progress pushes up wages enough so that fertility falls permanently. I will show below, however, that in the world before 1800 the best assumption seems to be that of the simple Malthusian model with fertility independent of income and mortality falling with higher incomes. There seems to be no Malthusian trap of this form, and there does seem to have been a profound change in the link between fertility and income in the late nineteenth century.

The Human Economy and Animal Economies

The economic laws we have derived above for the pre-industrial human economy are precisely those that apply to all animal, and indeed plant populations. Before 1800 there was no fundamental distinction between the economies of humans and those of other animal and plant species. Thus in evolutionary ecology the Malthusian model dominates as well.

For animal and plant species population equilibrium is similarly attained where birth rates equal death rates. Birth and death rates are both assumed to be dependant on the quality of the habitat (the analog of the human level of technology), and population density. In practice variations in death rate with population density seem most important in regulating population sizes, as we have assumed for human society. Ecological studies typically consider just the direct link between birth and death rates and population density, without considering the intermediate links, such as material consumption, as I have done above. But the Malthusian model for humans could also be constructed in this more reductionist way.

At least some ecological studies find that population density affects mortality in ways that are analogous to those we have posited for human population, through the supply of food available per animal. Thus Simon Mduma et al. "Food Regulates the Serengeti Wildebeest" show that over 40 years Wildebeest mortality rates depended largely on the available food supply per animal: "the main cause of mortality (75% of cases) was undernutrition" (Mduma et al. (1999), p. 1101). Hence the Industrial Revolution after 1800 represented the first break of human society from the constraints of nature, the first break of the human economy from the natural economy.

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Conclusion: Material Living Conditions from the Paleolithic to Jane Austen

This chapter lays out the grounds for the first claim made in the introduction, that living standards in 1800 were likely no higher than for our ancestors of the African Savanna. Since pre-industrial living standards were determined by fertility and mortality the only way living standards could be higher in 1800 would be because either mortality rates were greater at any given real income or fertility was lower.

This conclusion may seem too powerful. But consider for a moment the incomes and consumption standards of the poorest third of the English population in 1800, agricultural laborers. Even though England was then one of the richest economies in the world, agricultural laborers lived a pinched and by modern standards straightened existence. They worked about 300 days a year if in full employment, with just Sundays and the occasional other day off. The work day in the winter was all the daylight hours. Their regular diet consisted of bread, a little cheese, bacon fat and weak tea, supplimented by the adult males by beer. The diet was low in calories given the heavy manual labor, and they must often have been hungry. The monotony was relieved to some degree by the harvest period where work days were long, but the farmers typically supplied plenty of food. Hot meals were few since fuel for cooking was expensive. Similarly they generally slept once it got dark since candles for lighting were again beyond their means. They would hope to get a new set of clothes once a year. Whole families of 5 or 6 people would live in two room cottages, heated by wood or coal fires. There was almost nothing that they consumed – food, clothing, heat, light or shelter - that would have been unfamiliar to the inhabitants of ancient Mesopotamia. If consumers in 8,000 BC were able to get plentiful

food, including meat, and more floor space, while having to labor less, they could easily have

enjoyed a life style that English workers in 1800 would have preferred to their own.

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Table 1: Modern Fertility Rates and their Implications for Population

Country	Births Per Woman*	Population 2000* (millions)	Income Per Person** 2000, ($1996)	Projected Population in 2050
Spain	1.15	40.8	16,843	13
Italy	1.23	57.5	20,801	22
Japan	1.32	127.0	23,345	55
Germany	1.35	82.3	21,724	37
Canada	1.48	30.8	24,480	17
United Kingdom	1.60	58.7	21,076	38
France	1.89	59.3	21,716	53
USA	2.11	285.0	31,049	317
Brazil	2.21	171.8	7,130	210
Mexico	2.50	98.9	8,060	155
Egypt	3.29	67.8	4,013	183
Bangladesh	3.46	138.0	1,665	413
Saudi Arabia***	4.53	22.1	11,639	113
Oman***	4.96	2.6	14,985	16
Ethiopia	6.14	65.6	643	618
Yemen	7.01	18.0	1,213	221
Uganda	7.10	23.5	978	296
Niger	8.00	10.7	902	171

Note: The first column show the "Total Fertility Rate." This is the number of births a woman who reaches age 50 has on average. The last column is an estimate of the population computed assuming a generation of length 25 years, that all children survive, and that the current fertility rates have prevailed for many years.

*Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2002 Revision and World Urbanization Prospects: The 2001 Revision, http://esa.un.org/unpp

**Source: Penn World Tables : http://www.bized.ac.uk/dataserv/penndata/penn.htm

***Income Data is from 1996.

Table 2: Populations in Western Europe, 1340-1680

Year	1340	1550	1680
England	6	3	4.9
France	24	17	21.9
Italy	15	11	12.0
Germany	17	12	12.0
Spain	14	9	8.5
Netherlands	4	1.2	1.9
Western Europe	80	61	72

Sources: Hatcher, Plague, Population and the English Economy, 1348-1530 (1977), p. 71. E. A. Wrigley and R. Schofield, Population History of England and Wales, p. 232-3. E. A. Wrigley, "The Growth of Population in Eighteenth Century England: a Conundrum Resolved," Past and Present, 98 (1983).

Table 3: Birth Rates, Death Rates, and Population Growth Rates, 2000.

Country	Crude birth rate (per 1,000)	Crude death rate (per 1,000)	Natural Growth Rate (%), 2000	Growth Rate including Migration (%), 2000
Italy	8.8	10.9	-0.21	-0.10
Germany	8.7	10.6	-0.19	0.07
Japan	9.2	8.2	0.10	0.14
Spain	9.3	9.1	0.02	0.21
United Kingdom	11.0	10.4	0.06	0.31
France	12.8	9.3	0.35	0.47
Canada	10.3	7.5	0.28	0.77
USA	14.5	8.3	0.62	1.03
Brazil	19.7	7.1	1.26	1.24
Mexico	22.4	5.0	1.74	1.45
Egypt	26.6	6.2	2.04	1.99
Bangladesh	28.9	8.3	2.06	2.02
Ethiopia	42.5	17.7	2.48	2.46
Saudi Arabia	31.5	3.7	2.78	2.92
Oman	31.8	3.3	2.85	2.93
Uganda	50.7	16.7	3.40	3.24
Yemen	45.0	9.2	3.58	3.52
Niger	55.2	19.1	3.61	3.62

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2002 Revision and World Urbanization Prospects: The 2001 Revision, http://esa.un.org/unpp

Table 4: Labor Inputs per Day, Forager and Subsistence Societies versus England, 1800

Group	Location	Group or Activity	Hours/Adult Male/Day
Abelam[a]	Papua New Guinea	Subsistence agriculture, hunting	6.5
Ache[b]	Paraguay	Hunting	6.9
Aruni[p]	Papua New Guinea	Subsistence agriculture	5.2
Bemba[c]	Zambia	Shifting cultivation, hunting	3.4
Hiwi[d]	Venezuela	Hunting	3.0
Kayapo[e]	Brazil	Shifting cultivation, hunting, foraging	3.9
!Kung[f]	Botswana	Foraging	6.4
Machiguenga[g]	Peru	Shifting cultivation, foraging, hunting	6.0
Mikea[h]	Madagascar	Shifting cultivation, foraging	7.4
Shipibo[i]	Peru	Subsistence agriculture, fishing	3.4
Tatuyo[j]	Columbia	Shifting cultivation, hunting	7.6
Xavante[k]	Brazil	Shifting cultivation, hunting	5.9
Yanomame[o]	Brazil	Shifting cultivation, hunting, foraging	2.8
Average			**5.3**
Britain, 1800[l]		Farm laborers, paid labor	8.2
England, 1800[m]		Building Workers, paid labor	9.0
London, 1800[n]		All Workers	9.1

Sources: [a]Scaglion (1986), p. 541. [b]Kaplan and Hill (1992). [c]Minge-Klevana (1980). [d]Hurtado and Hill (1987), pp.178-9. [h]Tucker (2001), p. 183. [i]Bergman (1980), p. 209. [k]Lizot (1977), p. 514 (food production only).   [m]Table 5. [n]Voth (2001), p. 1,074. [p]Waddell (1972), p. 101.

Table 5: Building Workers Hours of Work, England 1750-1869

Decade	Towns	Observations	Simple average length of day (hours)	Average length of day (controlling for town and craft) (hours)
1750	1	2	12.0	12.0
1760	1	3	12.0	12.0
1770	-	-	-	-
1780	1	3	12.1	12.1
1790	2	9	11.8	11.8
1800	3	15	11.3	11.3
1810	4	20	10.3	10.3
1820	4	35	10.3	10.4
1830	5	21	9.9	10.0
1840	4	23	9.8	9.9
1850	6	25	9.7	9.8
1860	4	30	9.8	9.8

Note: The towns supplying observations are Barking, Bristol, Chelmsford, Colchester, Exeter, Hull, Leicester, London and Sutton Valence (Kent).

Sources: Bristol Record Office, Town Treasurer's Vouchers. Devon Record Office, Exeter Town Treasurers Vouchers. Essex Record Office, Quarter Session Vouchers. Leicester Record Office, Quarter Session Vouchers. London, Builders Price Books. London, Clothworkers, Wardens' Vouchers.

Figure 1: The Simple Malthusian Model - Birth and Death Schedules
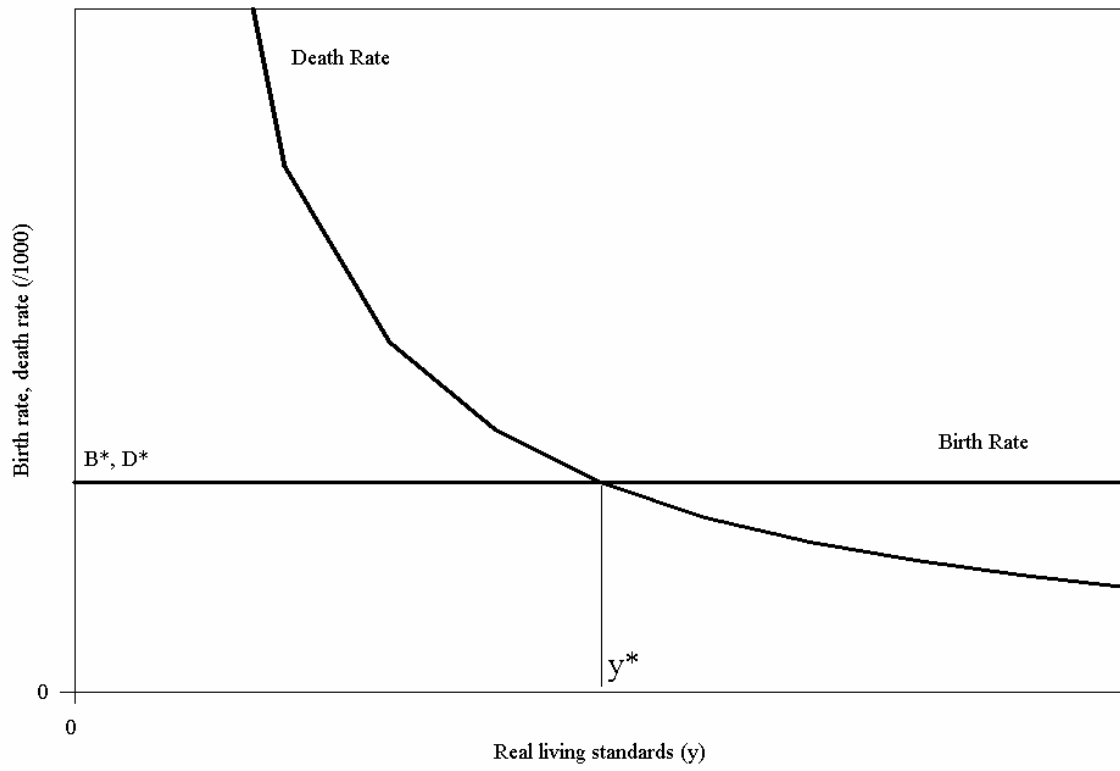
Figure 2: The Simple Malthusian Model - Technology Schedule
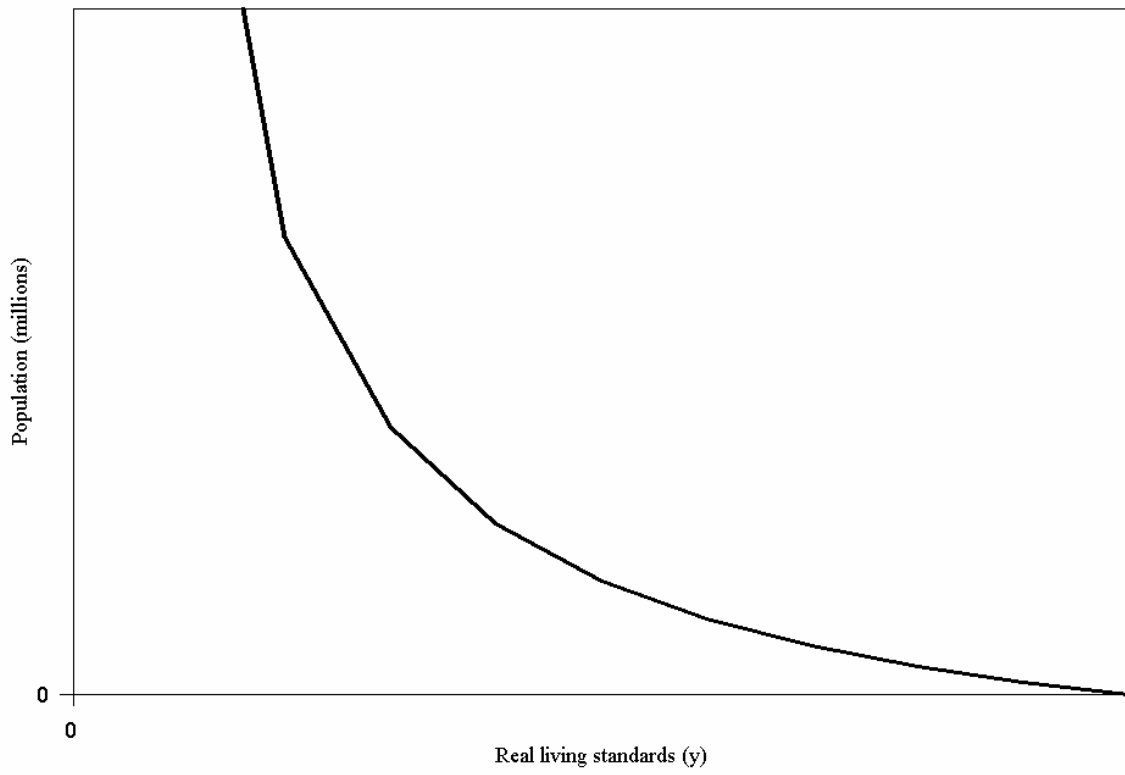
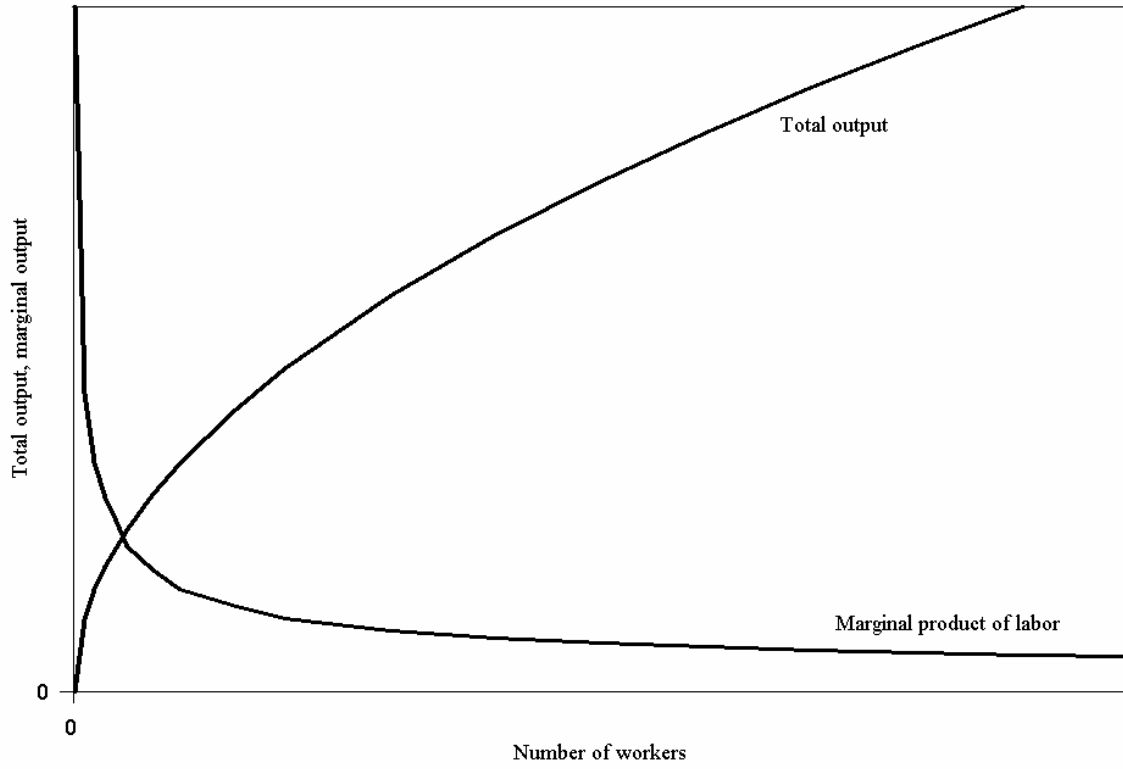**Figure 3: Labor Input and Output on a Given Area of Land**

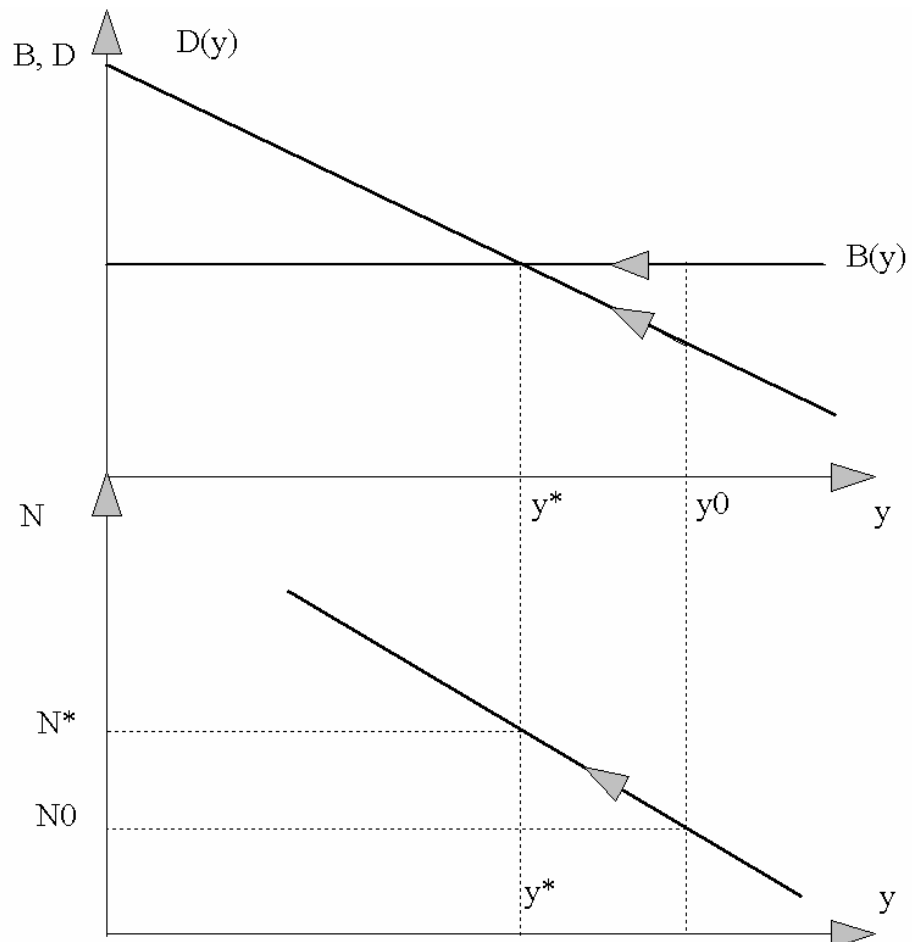**Figure 4: Long Run Equilibrium in the Malthusian Economy**
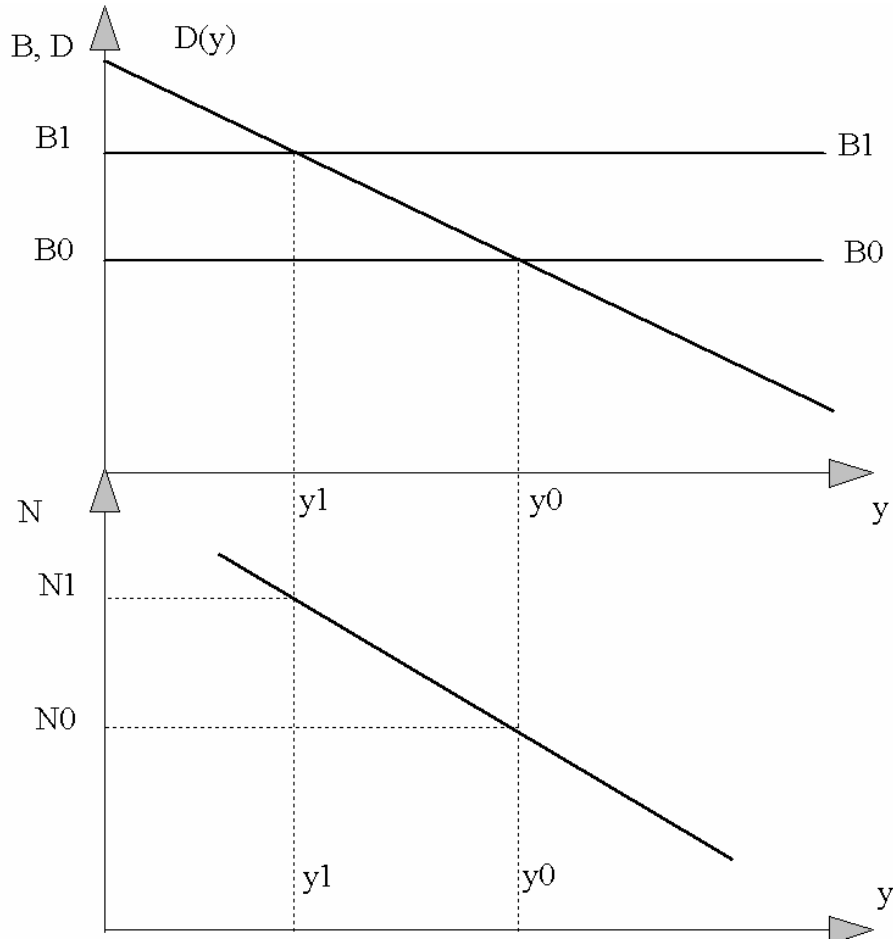
Figure 5: Changes in the Birth Schedule
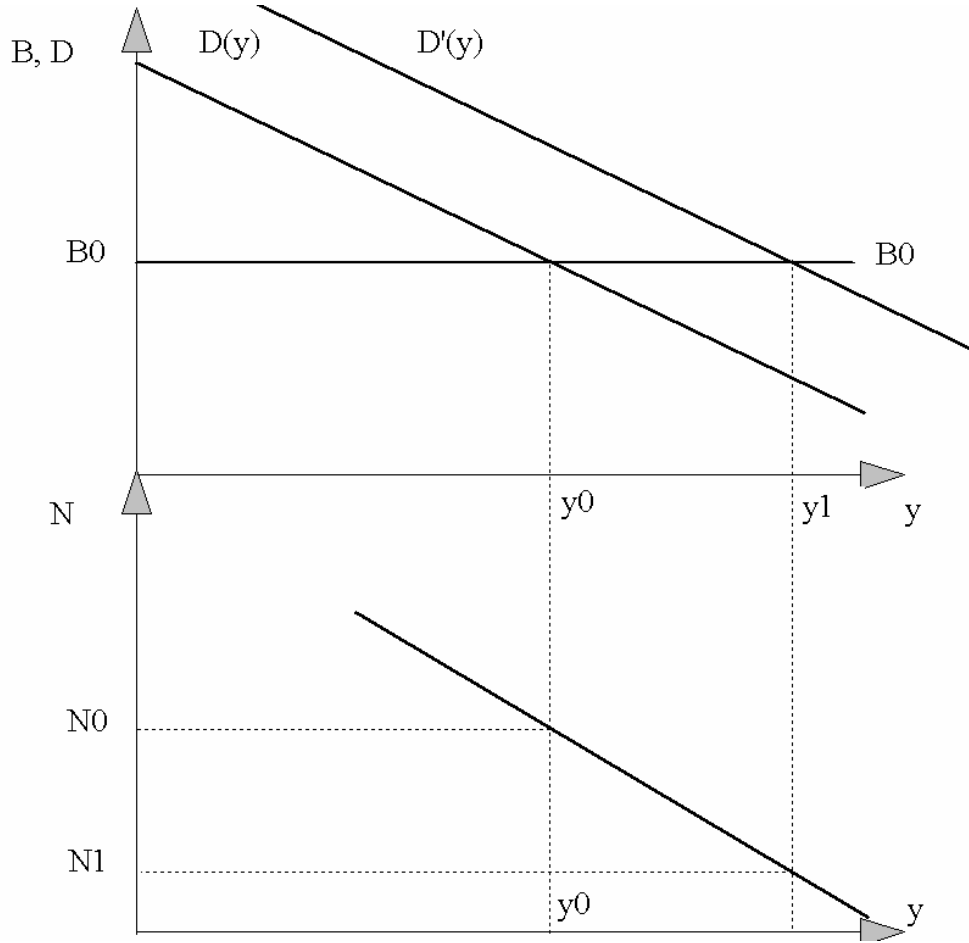
Figure 6: Changes in the Death Schedule
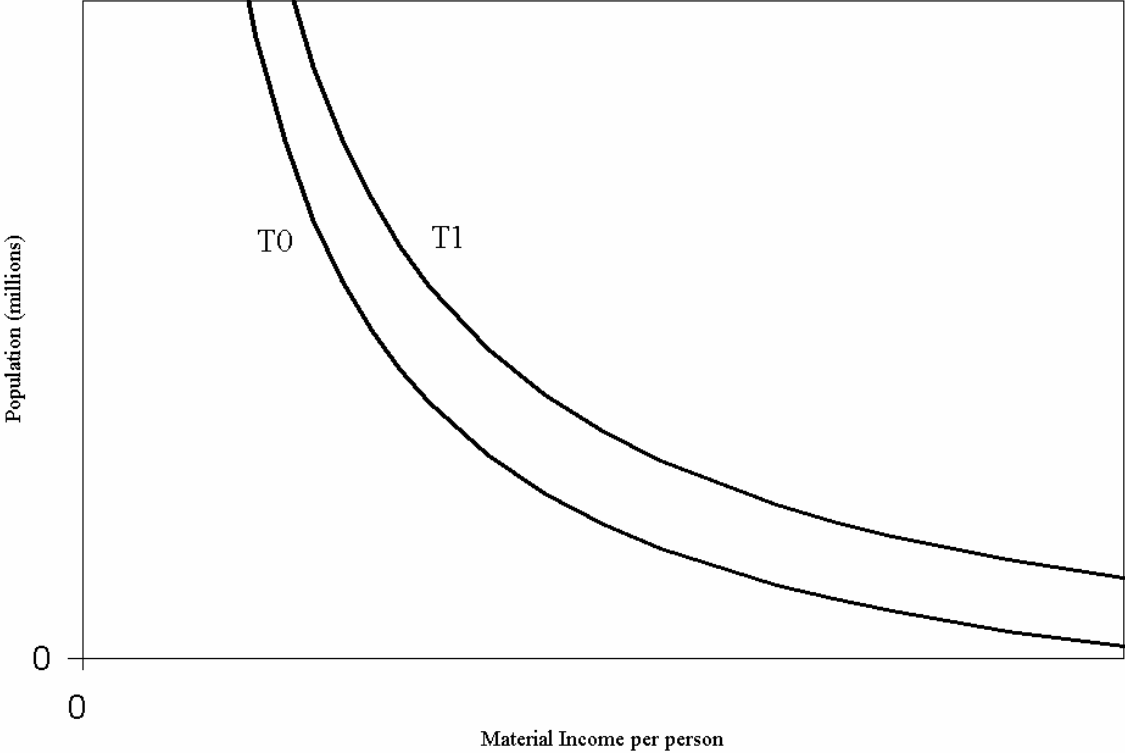
Figure 7: Changes in the Technology Schedule
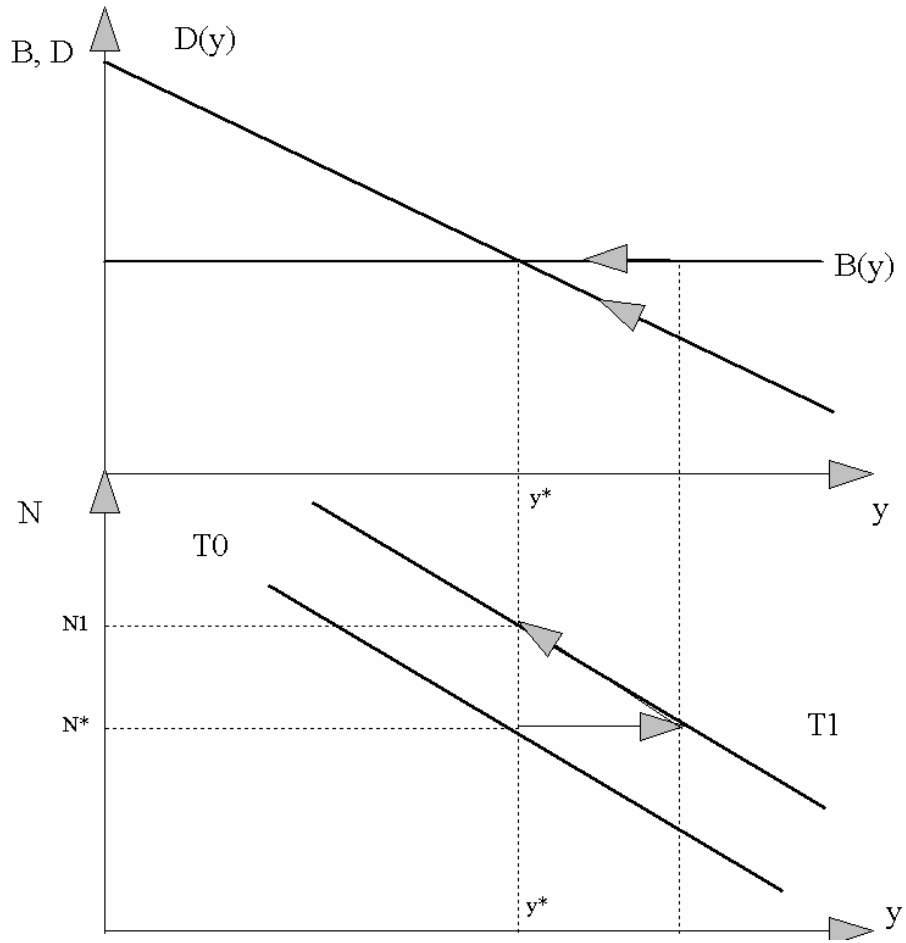
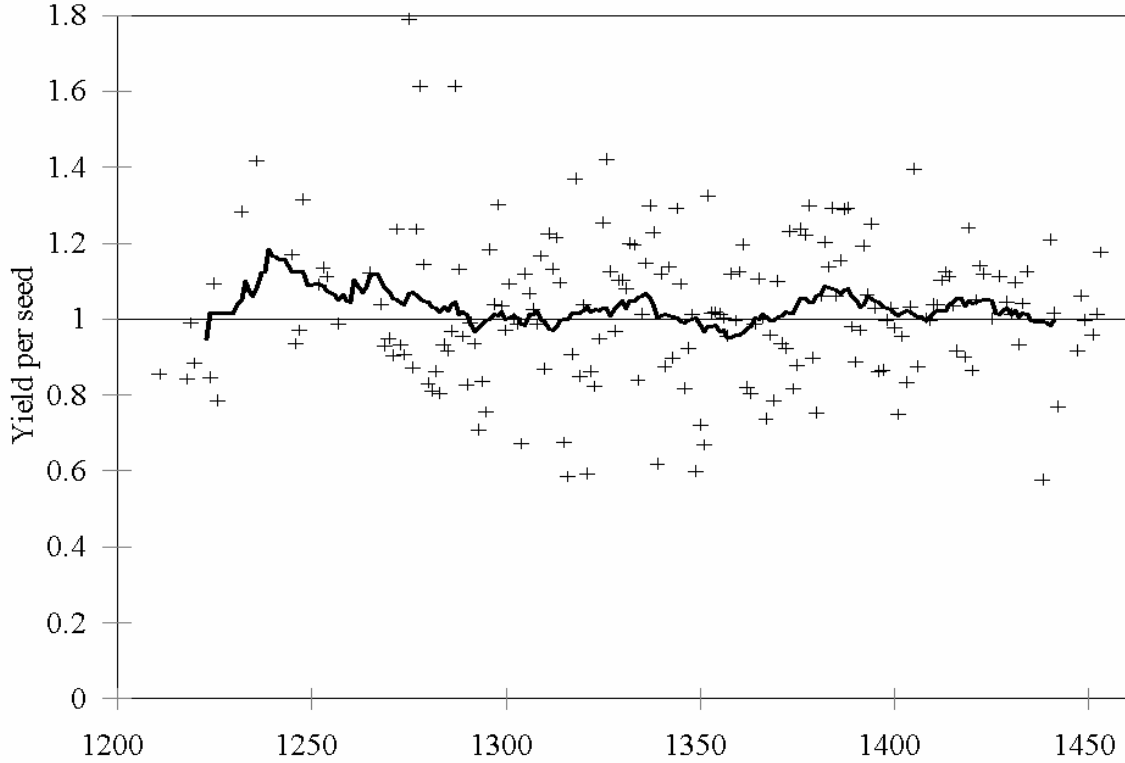**Figure 8: The Long Run Effect of Technological Advance**

Figure 9: Wheat Yields in England, 1211-1453

Note: Yields are measured as the number of grains harvested per grain sown, all normalized to the average yield over these years, controlling for differences in average yields across the farms in the sample. The solid line in the 25 year moving average of yields.

Sources: Titow (1972), Farmer (1983), Farmer Mss.

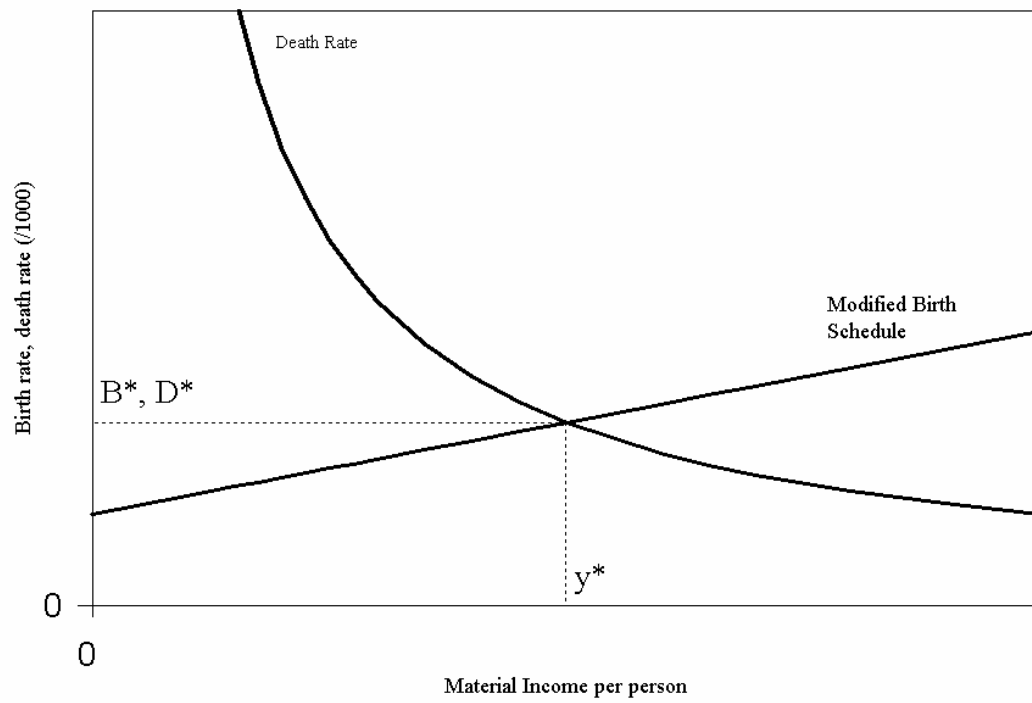**Figure 10: A Malthusian Model where Births Increase with Income**

Figure 11: A Malthusian Model where Births Decline with Income