Malthus and Pre-Industrial Stagnation

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The past two hundred years have seen a remarkable transformation in the standard of living of a substantial fraction of the world's population. Since about 1800, real wages of ordinary workers in Western Europe and North America have risen steadily by roughly one to two percent per year. This has lead to a cumulative increase in real wages of a staggering 1500%.

In sharp contrast, real wages of ordinary workers seem to have been largely stagnant before 1800. Figure 1 plots the real wage of laborers in the building industry in England from 1250 to 2000 on a logarithmic scale. The figure suggests that real wages in England were not trending upward before 1800. There were fluctuations. In particular, wages rose substantially between 1350 and 1450 as plagues ravished Europe. But they then subsequently fell back close to their prior level. As a consequence, the data in Figure 1 suggest that real wages in 1750 were not very different from their level 500 years earlier.

Whether long-run growth in real wages was exactly zero before 1800 or slightly positive is controversial. Constructing a series for real wages over a 750 year period is a monumental task and involves many choices about how best to use the very imperfect available data. However, not withstanding these controversies, it is clear that a major change occurred around 1800. Nothing even remotely like the 1-2% annual growth rates of real wages experienced over the last two hundred years has ever happened before in recorded history (as far as we can tell using current

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Figure 1: Real Wages of Laborers in England from 1250 to 2000

Note: This series is constructed by splicing together data from Clark (2010) for the period 1250 to 1860 and Clark (2005) for the period 1860 to 2000. The series is plotted on a logarithmic scale (base 2) and is scaled to be equal to 100 in the 1860s.

historical knowledge). This "modern sustained economic growth" first occurred in Britain around 1800. It then spread through Europe and to North America and subsequently to larger and larger parts of the globe. From an economic point of view, this is a major turning-point in history, perhaps the most important turning-point in all of history. Today we refer to this turning-point as the *Industrial Revolution*.

The Industrial Revolution raises several interesting questions. Why was there little or no growth before the Industrial Revolution? Why did the Industrial Revolution happen? Why did it happen in Britain? Why did it happen in the 18th and 19th centuries? Why did the Industrial Revolution lead to sustained growth rather than petering out as other periods of increased prosperity had before? The current state of knowledge on these big questions is highly imperfect. But even so, a substantial amount of interesting research has been done trying to shed light on these issues. In this chapter, we will discuss some major ideas regarding why there was little or no growth before the Industrial Revolution. Chapter XX covers the Industrial Revolution itself.

1 Measuring Real Wages and GDP Back to 1250

The data series in Figure 1 was constructed by the economic historian Gregory Clark building on earlier work by many scholars.[1] Recall that real wages refer to money wages adjusted for changes in the general price level. To construct a series for real wages, one must therefore gather data both on wages and prices. Not surprisingly, data on wages and prices become scarcer and scarcer the further back in time one goes. A great deal of detailed archival work and ingenuity in terms of finding data sources has gone into the construction of the series in Figure 1. The wage and price data that underlie this series come from a great variety of sources including the accounts of manors, monasteries, churches, colleges, charitable foundations, towns, guilds, and private households from all over England.

The process of going from the raw individual-level data to a summary measure of wages and prices involves a number of complications. For wages, the main complication is that one needs to adjust for changes in the composition of the dataset over time, i.e., compare "apples with apples." For example, wages differed from location to location. It is therefore important to adjust for variation over time in the geographical composition of the dataset (otherwise an increase in the index may be simply due to a larger fraction of quotes coming from high wage areas).

For prices, things are even more complicated. The first step is to construct price series for as many goods categories as possible. Clark constructs such price series for roughly 25 goods categories (e.g., bread, oats, potatoes, fish, eggs, beer, shelter, clothing, light). For each such series, it is important to adjust for changes in the composition of the data sample within the category (to make sure the price changes being measured are not simply due to Clark having data on goods of different quality over time). The second step is to then combine these many price series into a single overall index of the general price level. Clark does this by taking a weighted average using estimates of expenditure shares on each product category as weights. By using this method, Clark assumes that people's expenditure shares remain constant as the relative prices of different goods change over time (a less plausible but commonly used assumption in the construction of price indexes is that the quantity purchased remains constant as prices vary). These choices matter for some of the conclusions Clark comes to and in some cases are controversial.[2]

As I mention above, Clark's real wage series suggests that the level of real wages in England was almost identical in 1750 as it was 500 years earlier. In thinking about this conclusion, it is important to keep several things in mind. First, Clark's

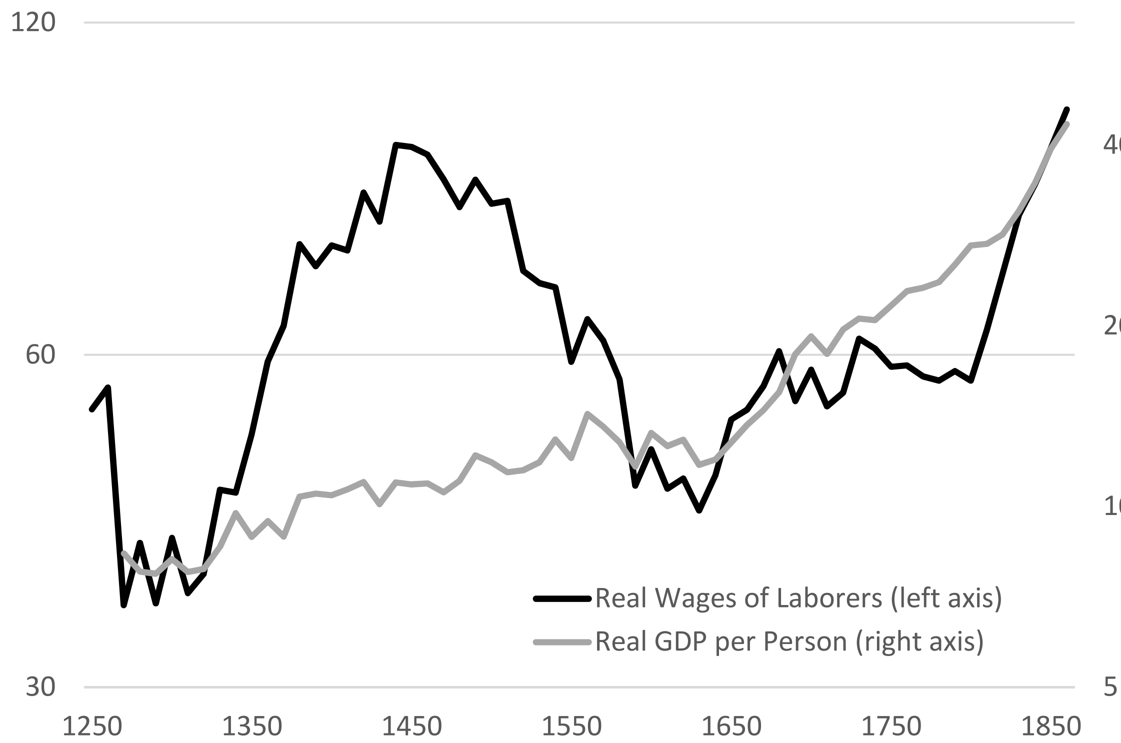

Figure 2: Real Wages and Real GDP per Person in England from 1250 to 1860

Note: The real wage series is the same as in Figure 1. Data on real GDP for England is from Broadberry et al. (2015). The real GDP series is divided by an estimate of the population of England from Clark (2010).

real wage series undergoes large and very persistent swings between 1250 and 1750. This makes it hard to precisely estimate the long-run growth rate of the series. Think about using a ruler to draw a line through this series representing the "trend." The slope of the line—i.e., the average growth rate—will depend on exactly which point you choose as your starting point and end point. For example, using 1270 as the starting point rather than 1250 yields a larger average growth rate since real wages fell substantially between 1250 and 1270. Exactly which point is the most appropriate starting point is a matter of judgment since we don't know what came before. The data in Figure 1, therefore, by no means rule out the idea of steady but very slow progress in England before 1800.

Second, Clark's data measure the real wages of laborers in building industries as opposed to per capita output in the economy. The growth rate of real wages and per capita output may not have been the same. Measurement of real GDP is a great deal more complicated than measurement of real wages. Broadberry et al. (2015) estimate real GDP for England back to the 13th century by adding up estimates of output in different sectors of the English economy (agriculture, industry, and services). Figure 2 plots this series along with Clark's real wage series. This real GDP per person series paints a strikingly different picture than the real wage series. It suggests that the English economy experienced relatively steady but slow growth going all the way back to 1270. According to Broadberry et al.'s series, real GDP per person was 140% higher in 1750 than in 1270.

What could explain this difference between the real wage series and the real GDP series? One potential explanation is that the share of output received by the working poor may have varied over time. Consider for example, the 18th century. Our data suggest that real GDP per person rose by 35%, while real wages fell by 2%. One reason for the difference may be that the lion's share of increased income in England in the 18th century may have gone to wealthier segments of the population—i.e., the merchant class involved in international trade and early industrialists—and therefore not benefited the working poor. In his book *Conditions of the Working Class in England in 1844*, Frederick Engels famously described industrialization in the 2nd quarter of the 19th century in England as overwhelmingly favoring capitalists while leaving real wages of the working poor stagnant (Engels, 1845/2009). The data in Figure 2 suggest that growth in real wages had actually picked up by the time of Engels' writing but that his description was quite apt for the 18th century in England. Economic historians often refer to the period of early growth in England when real wages lagged growth in output as 'Engels' Pause' (Allen, 2009).

Another reason why per capita output may have risen more than real wages is that a larger share of the population may have been working and those working may have worked more days per year in the 17th and 18th centuries than in earlier centuries. Humphries and Weisdorf (2019) present interesting evidence supporting this idea. They compare the wages of workers on annual contracts to Clark's series on the wages of day laborers. If workers were able to freely choose whether to work as day laborers or as annual workers, the difference in pay between the two types of contracts is likely to have been modest. In this case, dividing the payments to annual workers by the wages of day laborers provides an estimate of days worked per year. Humphries and Weisdorf's estimates suggest that days worked per year in England fell from about 200 prior to the Black Death down almost to 100 in the wake of the Black Death. After this, days worked per year rose steadily (if unevenly) back to 200 in the early 17th century and then kept rising to around 300 in 1800. This increased industriousness of English workers was part of a broader phenomenon in Western Europe that economic historians have dubbed the Industrious Revolution (de Vries, 2008).

Let me mention one additional issue to keep in mind when thinking about Clark's conclusion that real wages in England were virtually identical in 1750 as in 1250. Clark's calculations are heavily dependent on the price index he constructs. (Broadberry et al. use similar price indexes.) As we will discuss in much more detail in chapter XX [Measurement Chapter], it is quite difficult to accurately measure changes in the level of prices over long periods of time. One important source of bias is the appearance of new goods and quality improvements in existing goods. Standard methods for constructing price indexes do not adequately capture the decreases in the cost of living associated with new goods and quality improvement. Economic historians have pointed out that the range of consumer goods available to the average Briton in 1700 was far wider than 500 years earlier. This would suggest that Clark's price index rises more than it should have over this period. It is quite possible that adjusting for this "new goods bias" would increase the growth rate of Clark's real wage series by 0.1% or 0.2% per year.

2 Reasons for Stagnation

Scholars have identified several potential explanations for why living standards were largely stagnant before the Industrial Revolution. The most famous explanation is that population pressure prevented sustained increases in real wages. The idea is that whenever real wages rose this led to an increase in the population (since each family could afford to feed more children). As the population increased, wages would fall. This process would only stop when wages had fallen all the way down to subsistence. Although bits and pieces of this dismal logic are evident in the writings of many enlightenment thinkers around 1800, it was the English pastor and scholar Thomas Malthus who first laid it out fully and clearly in an essay he published in 1798 titled *An Essay on the Principle of Population* (Malthus, 1798/1993).

Another potentially powerful force impeding growth throughout most of history is risk of expropriation. Those who grew rich faced the risk that they would get attacked by others that found it easier to plunder than to produce wealth. This risk existed at many levels. Countries that grew rich faced a risk of invasion from neighboring countries, while individuals faced a risk of expropriation from rulers and other local bullies. As a consequence of this risk, a huge fraction of any economic surplus needed to be devoted to defense and the richer someone became, the more he or she would need to spend on defense. As the economic historian Joel Mokyr put it "in this way, growth, in a truly dialectical fashion, created the conditions that led to its own demise" (Mokyr, 2009, p. 7). Limiting the risk of expropriation in society is surely an essential precondition for sustained economic growth. The Industrial Revolution occurred in Britain, which is an island and therefore more secure against outside invasion, and also happened to be the country with the world's most advanced political institutions at the time. Perhaps this is not a coincidence.

A third potentially important reason for stagnation before the Industrial Revolution was widespread lack of individual freedom. Most people lived under various forms of serfdom or outright slavery. These people were typically not free to choose how to live their lives. For example, they could typically not choose whether they moved to a different part of the country or to a town, and what kind of work to engage in. Furthermore, rural peasants' incentives to make changes to the farming methods they used—to the extent that they were allowed to make such changes at all—must have been very weak since any benefit was likely to be heavily taxed by the feudal lord. Even people that lived in towns often faced severe restrictions on occupational choice. Sons were in many cases, for all practical purposes, required to carry on the professions of their fathers. In such a society being illegitimate had the perverse benefit that it allowed for more occupational freedom. Leonardo da Vinci is a particularly famous example of an illegitimate son that was thankfully able to choose his own profession. This lack of occupational freedom likely meant that many talented people were never able to fully make use of their talents by choosing to work in the area in which they had a comparative advantage and where they were more likely to make improvements on existing methods and knowledge.

A fourth powerful force that impedes growth is vested interests favoring the status quo. Much advancement involves change. In many cases, change threatens the interests of those that have attained relative wealth and power within the old system since they may fear that they will not fare as well in the new system. These powerful actors will resist change and thereby impede growth. Often, change occurs because of new ideas. A key element of resisting change therefore has to do with preventing the spread of new ideas. In this vein, powerful actors have often enforced severe restrictions on freedom of thought and freedom of expression, frequently under religious auspices. One important contributing factor to stagnation throughout most of history is therefore likely that the technology for suppressing new ideas and destroying knowledge may have been more effective than the technology for spreading new ideas and maintaining knowledge, as I discuss in more detail in chapter XX [Industrial Revolution Chapter].

The invention of the movable type printing press around 1450 by Johannes Gutenberg in modern-day Germany was arguably a watershed moment that greatly changed the balance of power in Europe between those seeking to preserve and spread ideas and those seeking to suppress them. In the 50 years following the invention of Gutenberg's printing press, more books were produced than in the proceeding thousand years (Buringh and van Zanden, 2009).[3] The Reformation, then the Scientific Revolution, then the Enlightenment, and then the Industrial Revolution (along with political revolutions in the Netherlands, England, the United States, France, and elsewhere) occurred in relatively rapid succession after the invention of the printing press. It certainly seems that there was a break in the speed of the accumulation of new knowledge around this time. But of course many other things are going on at the same time. So, proving how large a role the printing press played in these developments is difficult.

3 The Malthus Model

To better understand Malthus' idea that population pressure will prevent real wages from rising much above subsistence, it is useful to write down a formal model that captures this idea. In doing this, I will not be fully faithful to all of Malthus' original ideas. Some aspects of what Malthus argued have fared worse than others. For example, he argued that the population could grow exponentially (1, 2, 4, 8, 16, etc.), while "the means of subsistence"—what we would call productivity—can only grow arithmetically (1, 2, 3, 4, 5, etc.). This idea is not necessary to make Malthus' basic point (and is also empirically dubious). Errors and imprecisions like these—and there are others in Malthus' original essay—illustrate well the value of writing down formal mathematical models of complicated ideas like the ones Malthus is seeking to explain.

The first building block of the model is a production function. Consider the following production function

$$Y_t = A_t D^a L_t^{1-a}, \tag{1}$$

where Y_t denotes the quantity of output produced at time t, D denotes the quantity of land available, L_t denotes the amount of labor available at time t, A_t denotes the level of productivity at time t, and a is a parameter that takes a value between zero and one. Malthus had in mind a primarily agricultural economy. In such an economy, land is an important factor of production. A crucial feature of land is that it exists in fixed supply. For this reason, D doesn't have a time subscript in equation (1) (it can't change over time).

We have assumed that the production function takes the Cobb-Douglas form. It is therefore constant returns to scale in labor and land. This means that if it were possible to double both labor and land, output would double. However, since the supply of land is fixed, this is not possible. The only factor of production that can be increased in this model is labor and the production function is decreasing returns to scale in labor alone. This fact plays a key role in how the model works.

The second building block of the model is a labor demand curve. We assume that the labor market is competitive. As we saw in chapter XX [Labor Supply Chapter], this implies that employers will hire labor up until the point where the marginal product of labor equals the wage. Labor demand is therefore given by

$$w_t = (1-a)A_t\left(\frac{D}{L_t}\right)^a, \tag{2}$$

where w_t denotes the real wage. The fact that there are diminishing returns to labor in the production function implies that the marginal product of labor (the right-hand-side of this equation) is decreasing in L_t. This implies that the real wage will fall when the population rises.

The third building block of the model is a labor supply curve. Malthus' theory of labor supply is really a theory of population growth. To see how this can be the case, we decompose the amount of labor supplied into the number of people working (denoted N_t) times the number of hours of labor each person supplies (denoted H_t):

$$L_t = H_t N_t. \tag{3}$$

We assume for simplicity that hours per worker remain constant, i.e., $H_t = H$. This implies that labor supply is driven by changes in the population. Here we abstract, for simplicity, from the evidence presented in Humphries and Weisdorf (2019) (and discussed above) that days worked per year varied appreciably in England over the period 1250-1800.

The basic idea underlying Malthus' theory of population is that people have a natural tendency to continually produce children and that absent certain checks, this will lead the population to grow. Malthus discussed various potential checks on population growth and classified these checks into "positive checks" that increased death rates and "preventive checks" that reduced birth rates. Positive checks include disease, war, severe labor, and extreme poverty. Preventive checks include contraception, delayed marriage, and reduction in the frequency of coitus during marriage.

In the simplest formulation of Malthus' model—which we will adopt for now—abject poverty is the only check that is sufficiently strong to stop the population from growing. One way to think about this version of the model is the following: Birth rates are very high because women marry early and married couples cannot control their fertility. For the population to be stable, death rates must also be very high. (The population grows whenever birth rates are higher than death rates.) It is only at extreme levels of poverty that the death rate rises to a high enough level to stop the population from growing. If wages are higher, death rates are lower and the population grows.

We can also think about this from the perspective of a particular family: The parents have a continual stream of children since they can't control their sexual passions. Many of these children die. The poorer the household is, the more likely their children are to die. If wages are high enough that the family can provide well enough for their children that more than two of them survive to adulthood on average, the population will grow. But at some level of poverty—i.e., some level of real wages—the death rate of the children rises to a point where only two survive to adulthood on average. At this point the population is stable.

The following dynamic equation captures these ideas in a simple way:

$$N_{t+1} = \frac{w_t}{w^s} N_t. \tag{4}$$

This equation determines the population next period (N_{t+1}) as a function of two things: the population this period (N_t) and the ratio of real wages this period (w_t) and the "subsistence wage" (w^s). The subsistence wage w^s is the level of wages that is just high enough that two children survive to adulthood for each family on average. If the wage is at this level, the population will remain constant. To see this, notice that when the wage at time t is at the subsistence level, i.e., $w_t = w^s$, equation (4) simplifies to $N_{t+1} = N_t$.

It is convenient to rewrite equation (4) as

$$\frac{N_{t+1}}{N_t} = \frac{w_t}{w^s} \tag{5}$$

by dividing through by N_t. It is easy to see that whenever the wage is above the subsistence level, i.e., $w_t > w^s$, the population is growing ($N_{t+1}/N_t = w_t/w^s > 1$ which implies that $N_{t+1} > N_t$). Conversely, whenever the wage is below the subsistence level, the population is shrinking.

The ideas and equations described above are all we need to understand how population pressure leads to stagnation of living standards. However, to make sense of data on wages and population from the middle ages, we need to include one additional aspect of medieval reality, namely plagues. Plagues were frequent in Europe in the 14th through 17th centuries and led to a large and protracted decrease in the population of Europe between 1300 and 1450, which largely reversed over the subsequent 200 years.

A simple way to model plagues is as an exogenous shock that affects population growth. Incorporating this shock into our model yields the following augmented version of equation (5) for population growth:

$$\frac{N_{t+1}}{N_t} = \left(\frac{w_t}{w^s}\right) \xi_t. \tag{6}$$

Here ξ_t denotes the plague shock at time t. The symbol ξ is the Greek letter xi. In most years there is no plague. In this case, $\xi_t = 1$. Ever so often, however, the plague strikes. In these years, $\xi_t < 1$. In other words, the plague leads the population to shrink relative to what it would have done otherwise.

Plagues are, of course, not the only events that affect population growth in this way. Wars have similar effects. Warfare was particularly intense and casualties particularly high as a proportion of the population in Europe in the 14th through 17th centuries. The Religious Wars in France in the late 16th century are estimated to have killed approximately 20% of the French population, while estimates indicate that roughly a third of the population of Germany died because of the Thirty Years War of 1618-1648.[4] The death rates caused by these wars were so enormous partly because the armies involved spread disease and hunger (Voigtländer and Voth, 2013a). Another type of event that reduces population growth is bad weather that leads to a bad harvest and thereby causes a famine to occur. Such climate induced famines played a role in population dynamics in Europe in the 17th and 18th centuries. But their effects were not nearly as dramatic as those of plagues and wars. For simplicity, in what follows, I will use the word plague to refer to all events of this sort.

3.1 A Plug-and-Chug Solution of the Model

Let's now use equation (3) to plug in for L_t in the labor demand equation (equation (2)). This yields a new version of the labor demand equation written in terms of the population:

$$w_t = (1-a)A_t\left(\frac{D}{HN_t}\right)^a. \tag{7}$$

Equations (6)—the population growth equation—and equation (7)—the labor demand equation—are the key equations of the Malthus model. Notice that these equations are two equations with two endogenous variables—w_t and N_t—for each time period t. Two equations with two unknown variables suggests that the model should be easy to solve with simple algebra. There is a twist, however. The twist is that the Malthus model is a *dynamic model*. Notice that the population equation involves the population both at time t and at time $t+1$. The population equation therefore provides a link between time t and time $t+1$ which means that the equilibrium outcomes in period $t+1$ will be influenced by what the equilibrium outcomes were in period t. Models that have this feature are called dynamic models. At a more mechanical level, we have to face the fact that equations (6) and (7) actually involve three endogenous variables: w_t, N_t, and N_{t+1}. Two equations are clearly not enough to solve for three endogenous variables. So, we need a different approach for solving the model than the one we use in a static (i.e., non-dynamics) setting.

We can actually simplify the model by using the labor demand equation to eliminate the wage rate from the population equation. Using equation (7) to plug in for w_t in equation (6) yields

$$N_{t+1} = \phi A_t \xi_t N_t^{1-a}, \tag{8}$$

where I have defined a new constant $\phi = (1-a)D^a/(w^s H^a)$ to reduce the messiness of this equation. Notice that given an initial population N_0 and values for the exogenous variables A_t and ξ_t at all points in time, one can use equation (8) to solve for all future levels of the population through the following iterative process: Start with N_0. Use the $t=0$ version of equation (8) to solve for N_1 as

$$N_1 = \phi A_0 \xi_0 N_0^{1-a}.$$

Now that we have N_1, use the $t=1$ version of equation (8) to solve for N_2 as

$$N_2 = \phi A_1 \xi_1 N_1^{1-a}.$$

And so on. Furthermore, after we have solved for the population in a particular time period, we can use the labor demand equation for that time period to solve for the wage in that time period. For example, once we know N_1, we can use the labor demand equation for $t = 1$ to solve for w_1 as

$$w_1 = (1-a)A_1 \left(\frac{D}{HN_1}\right)^a .$$

When one solves the model in this way, it is important to remember that since A_t and ξ_t are exogenous, they should be considered given. The model does not provide a theory for the exogenous variables A_t and ξ_t. So, one needs to be given values for them to be able to solve the model.

The dynamic nature of this model adds the twist that one also needs to be given an initial value for the population. The model does not provide a theory for the initial value of the population. It is therefore also an exogenous variable that needs to be given for it to be possible to solve the model. This is how we got around having two equations with three unknown variables.

3.2 A Graphical Solution of the Model

While the iterative solution method described above is quite simple, it is rather mechanical and does not deepen one's understanding of the economic forces at play. An alternative way to solve this model, which is useful in that it brings out the economic forces at play more clearly is to use a graphical solution method. The key to this graphical solution method is Figure 3. Here I plot the simplified population growth equation (equation (8)) with N_t on the x-axis and N_{t+1} on the y-axis. For simplicity, I do this for a particular level of productivity $A_t = 1$ and assuming that there is no plague ($\xi_t = 1$). In other words, I plot what the Malthus model implies the population in period $t + 1$ will be as a function of what the population is in period t when $A_t = 1$ and $\xi_t = 1$. Let's refer to this line as the *population growth line*. Notice that the population growth line is concave since N_{t+1} is equal to a constant times N_t raised to a power between zero and one (equation (8)).

I also plot for convenience the 45° line: $N_{t+1} = N_t$. This $N_{t+1} = N_t$ line is simply a visual aid in Figure 3. For each level of population N_t, this line indicates how high the population growth line needs to be for the population to remain unchanged. Notice that the population growth line crosses the $N_{t+1} = N_t$ line at a point that I have denoted by $\bar{N}$. This level of the population is special since if the population starts at this level, it will remain at this level. We call the population level $\bar{N}$ a *steady state* population level. To the left of $\bar{N}$, the population growth line lies above the

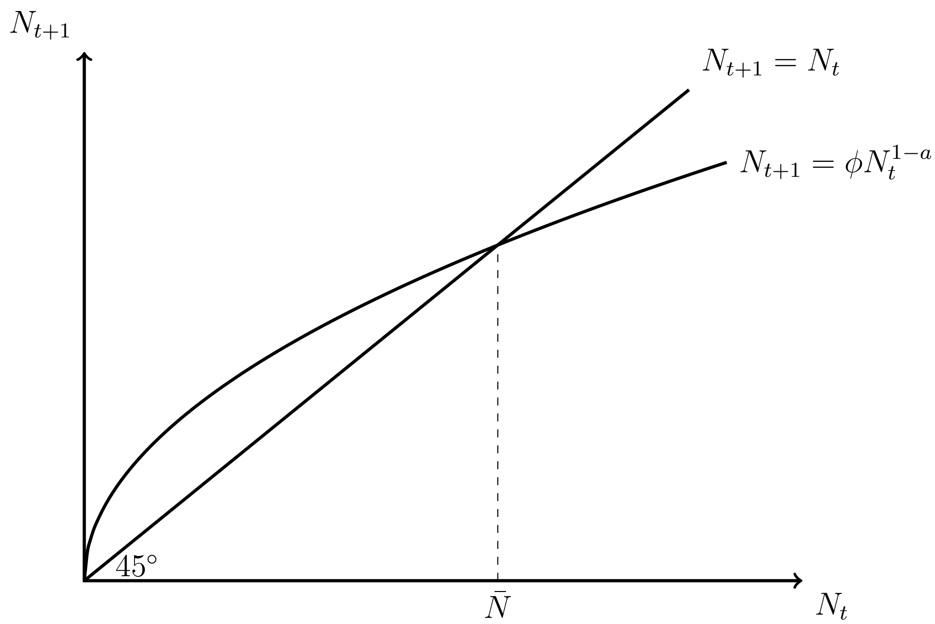

Figure 3: Graphical Solution of Malthus Model

$N_{t+1} = N_t$ line. In this region N_{t+1} will be larger than N_t, i.e., the population will be growing. To the right of $\bar{N}$, the population growth line lies below the $N_{t+1} = N_t$ line. In this region N_{t+1} will be smaller than N_t, i.e., the population will be shrinking.

Let's consider an example. Suppose the population starts at a level $N_0 < \bar{N}$. This situation is depicted in Figure 4. The level of the population in period 1 is then given by the value of the population growth line at N_0—point A on Figure 4. Since the population growth line lies above the $N_{t+1} = N_t$ line, the population is growing and $N_1 > N_0$ and therefore closer to $\bar{N}$. Once we have found N_1 in this way, we can use the same method to find N_2—point B on Figure 4. Since the population line is still larger than the $N_{t+1} = N_t$ line at N_1, $N_2 > N_1$ and therefore still closer to $\bar{N}$. Repeating this process over and over again it is easy to see from Figure 4 that the population will *converge* over time to $\bar{N}$.

The same argument holds for any other starting point $N_0 < \bar{N}$. If on the other hand, we start with $N_0 > \bar{N}$, the population will shrink over time since the population equation is below the $N_{t+1} = N_t$ line to the right of $\bar{N}$. An analogous iterative process as is described above but starting from points to the right of $\bar{N}$ shows that in this case the population will also converge over time to $\bar{N}$.

This graphical analysis shows that in the Malthus model when the level of productivity is constant and there are no plagues the population will converge to a certain level (denoted by $\bar{N}$ in our figures) no matter where it starts off. If the popu-

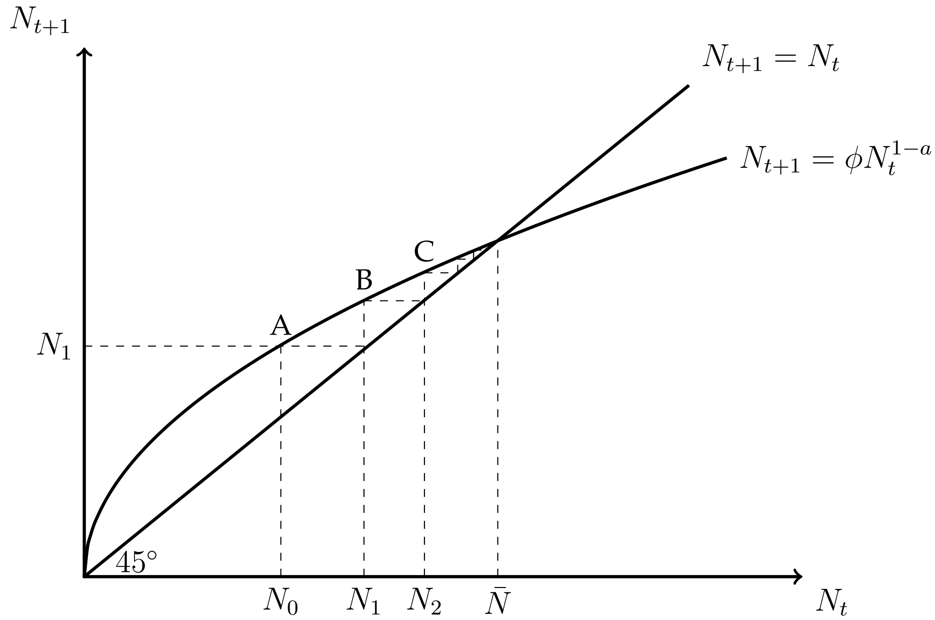

Figure 4: Population Convergence in the Malthus Model

lation starts off being higher than $\bar{N}$, then it will shrink until it reaches $\bar{N}$. If it starts off at a lower level than $\bar{N}$, it will grow until it reaches $\bar{N}$.

It is relatively simple to solve analytically for the steady state population level $\bar{N}$. The key "trick" is to make use of the fact that we know that at the steady state, the population is not changing. In other words, at the steady state $N_{t+1} = N_t = \bar{N}$. This implies that when we are solving for the steady state we can plug $\bar{N}$ in for N_{t+1} and N_t in equation (8). This yields $\bar{N} = \phi \bar{N}^{1-a}$ (assuming again that $A_t = 1$ and $\xi_t = 1$). Solving this equation for $\bar{N}$ then yields

$$\bar{N} = \phi^{1/a}. \tag{9}$$

What about real wages? Figure 5 plots the labor demand curve in the Malthus model (equation (7)) assuming again that $A_t = 1$. The labor demand curve is downward sloping. Recall that the labor demand curve tells us how many workers the employers in the economy are willing to hire at different wage rates. Since we assumed that labor markets are competitive, labor demand is governed by the marginal product of labor. The labor demand curve is downward sloping because the marginal product of labor falls as the population rises.

We can use Figure 5 to assess how real wages evolve in the model as the population changes. Above, we saw that the population converges to $\bar{N}$ when the level of productivity is constant and there are no plagues. At this steady state population

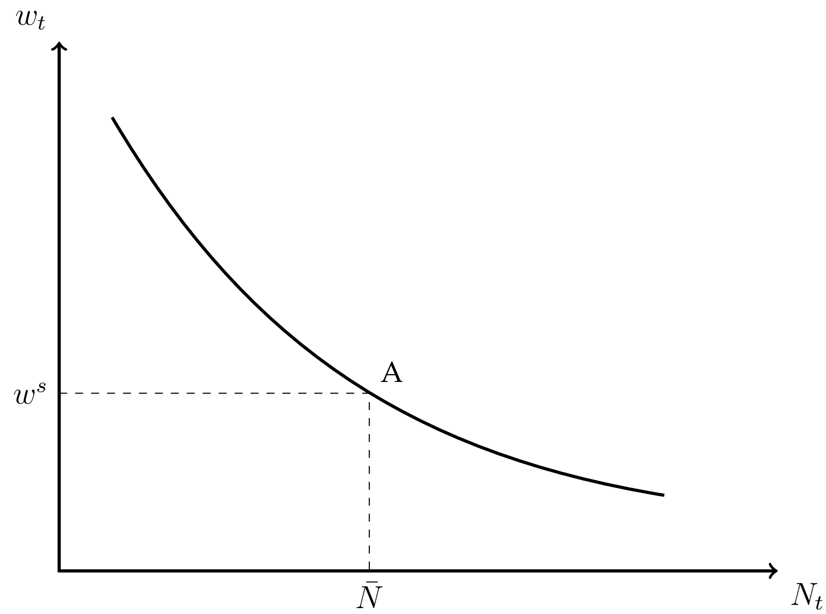

Figure 5: Labor Demand in the Malthus Model

level, real wages will be at subsistence. If the population, however, starts off at a higher level (i.e., $N_0 > \bar{N}$), then the real wage will be below subsistence. It is exactly because real wages are below subsistence that the population will shrink (people's wages are so low that they can't feed two children). As the population shrinks—i.e., when we move to the left in Figure 5—real wages rise. The population will stop shrinking exactly when wages reach subsistence (since that is the point at which families' incomes are high enough to feed two children). The logic is the same if the population starts off at a low level. In that case, real wages are high and according to the assumptions of the model, families choose to have more than two children. This leads the population to increase. The increase in the population, in turn, leads the real wage to fall. This whole process continues until the real wage has fallen all the way to subsistence. This logic implies that real wages will converge to subsistence no matter where it starts off, a property often referred to as the *Iron Law of Wages*.

It is clear from this discussion that the downward slope of the labor demand curve in Figure 5 is a key determinant of the discouraging conclusion of the Malthus model that real wages will always converge to the subsistence level. The economics behind this downward slope is diminishing returns to labor when the amount of land available is fixed. When the population is large there are "too many" people working the land. The large number of people working the land implies that the marginal product of labor is very small (smaller than the subsistence wage). Since wages are determined by the marginal product of labor, wages will be below subsistence.

The situation would be very different if land was not fixed. Suppose for example that people could invest in new land (e.g., clearing forests, landfills, or discovering new continents). In this case, as the population rose, the marginal value of investing in new land (the marginal product of land) would rise. This would lead to more investment in land and eventually in more land coming online. If the cost of investing in land were sufficiently low that the quantity of land could keep pace with growth in the population, then the marginal product of labor would not fall as the population increased (since land would increase just as much). This would mean that Malthus' conclusion about wages falling to subsistence would no longer hold.

One of the things that has happened over the past 250 years is that the importance of land as a factor of production has decreased a great deal while the importance of physical capital has increased. Since the stock of physical capital is much more easily increased through investment than the stock of land, the Malthusian force leading to low real wages has become less important than before.

3.3 The Consequences of a Plague

As we noted above, plagues were a major source of variation in the population of Europe between the years 1300 and 1600. When a plague strikes, it leads to a sharp drop in the population. That much is obvious. But how does the plague affect living standards for those that survive? Are the effects of the plague on the population and living standards permanent? Or do they partially or even fully go away as time passes? The Malthus model provides one possible set of answers regarding these questions. Of course, the Malthus model is just a theory. Whether this theory is correct can only be assessed using empirical evidence. We will do this in section 5.

Let's consider what the Malthus model implies about the evolution of the population and real wages (living standards) after a plague strikes. Figure 6 presents the population growth figure and the labor demand figure for this case. Let's assume for simplicity that the economy starts off in a steady state in which the level of the population is $\bar{N}$ and the real wage is at its subsistence level w^s. Suppose a plague strikes in period 0. The way we model the plague at time 0 is as a value of $\xi_0 < 1$. Since the economy was in steady state before the plague strikes, the population in period 0 is $\bar{N}$ and real wages in period 0 are w^s. Plugging these values into the $t = 0$

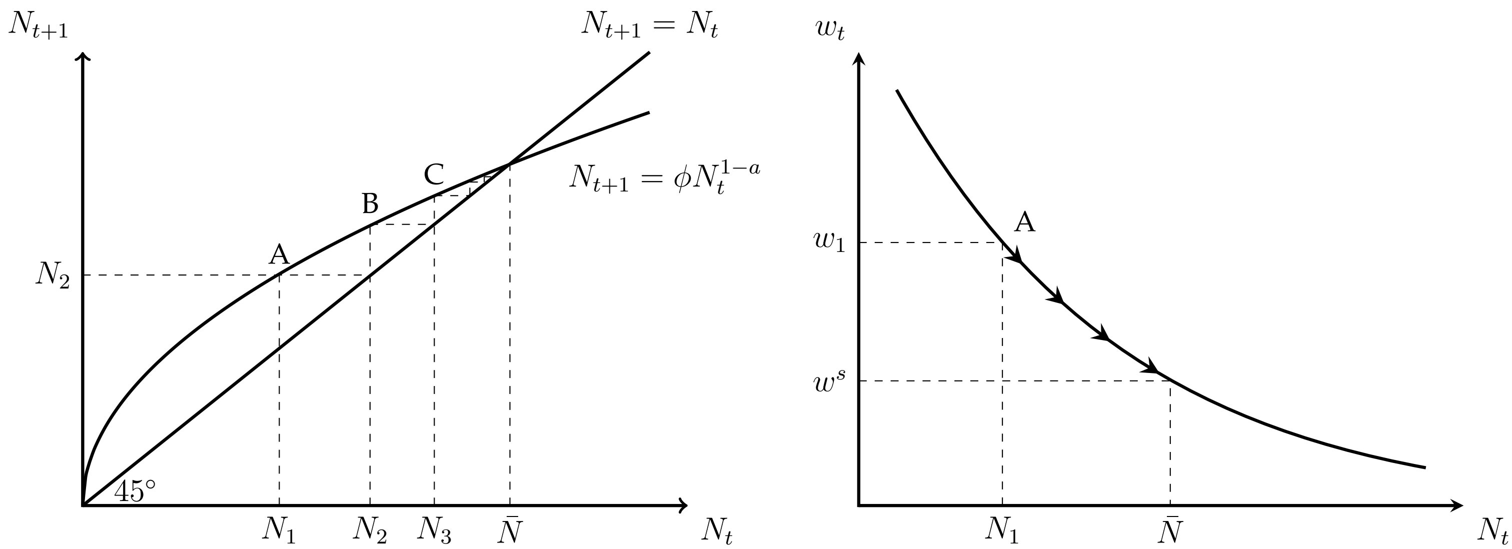

Figure 6: The Consequences of the Plague

version of equation 6, we get that

$$N_1 = \xi_0 \bar{N}. \tag{10}$$

The plague therefore kills a fraction $1 - \xi_0$ of the population when it strikes.

In the next period, the plague has passed. Population growth is therefore again dictated by the normal population growth line. The population in period 2 is then the value of this normal population growth line at N_1 (point B in Figure 6). Point B is above the $N_{t+1} = N_t$ line, which implies that the population is rebounding, i.e., $N_2 > N_1$. In period 3, the normal population growth line applies again and we can use the same logic to find N_3 (point C in Figure 6) and so on. If we repeat this logic enough times, we see that the population eventually converges back to $\bar{N}$. The plague therefore only has a temporary effect on the population in the Malthus model.

Notice that the process for solving for the evolution of the population after the plague has passed is the same as in section 3.2 (see Figure 4). The only difference is what happens at the time that the plague strikes. What happens at that time provides one explanation for why the population could even end up being away from the steady state. Since the population always converges to the steady state, one might ask how it would even end up being anywhere else. One answer is that a plague might strike.

The labor demand figure (the right panel in Figure 6) helps us understand the consequences of the plague for real wages. The plague does not shift the labor demand curve (see equation (7)). Rather, the decrease in the population from $\bar{N}$ to N_0 moves the economy to a different point on the labor demand curve at which wages are higher (point A). The economic intuition for this is that there are fewer people to work the same amount of land. This implies that the marginal product of labor is higher than before. Since wages are equal to the marginal product of labor in the Malthus model, wages rise when the population falls. The Malthus model therefore implies that the horrendously tragic human suffering brought about by a plague turn out to benefit those that survive, at least when it comes to their income. The economist Alwyn Young has recently written about this same phenomenon in the context of the AIDS epidemic in Africa and referred to it as the "gift of dying" (Young, 2005).

As the population rebounds back to $\bar{N}$ in the years after the plague, the economy moves back along the labor demand curve to w^s. Since the population rebounds fully back to its initial level of $\bar{N}$, the initial increase in real wages also reverses fully in the long run.

It is useful to visualize the effects of the plague on the population and real wages using *time series graphs*. A time series graph plots the evolution of a variable such as the population or the real wage over time. Figure 7 plots time series graphs for the population and the real wage before and after a plague. Before the plague strikes, the population and real wages are at their steady state levels of $\bar{N}$ and w^s. When the plague strikes, the population jumps down and real wages jump up. After the plague passes, both population and the real wage return slowly back to their steady state levels.

3.4 The Consequences of a Change in Technology

Improvements in technology are often considered a key driver of increases in economic well-being. Narrative histories of technological progress suggest that improvements in technology were few and far between before the Industrial Revolution (Mokyr, 1990). However, some important improvements did occur. Three important improvements in agricultural technology in the early Middle Ages were the heavy plow, the three-field system of crop rotation, and the modern horse collar. These three improvements together increased agricultural productivity substantially. However, data on labor earnings from the pre-industrial period suggest that the standard of living of most people in most places was close to subsistence (see e.g., Allen, 2009, ch. 2). An important question is why the accumulation of techno-

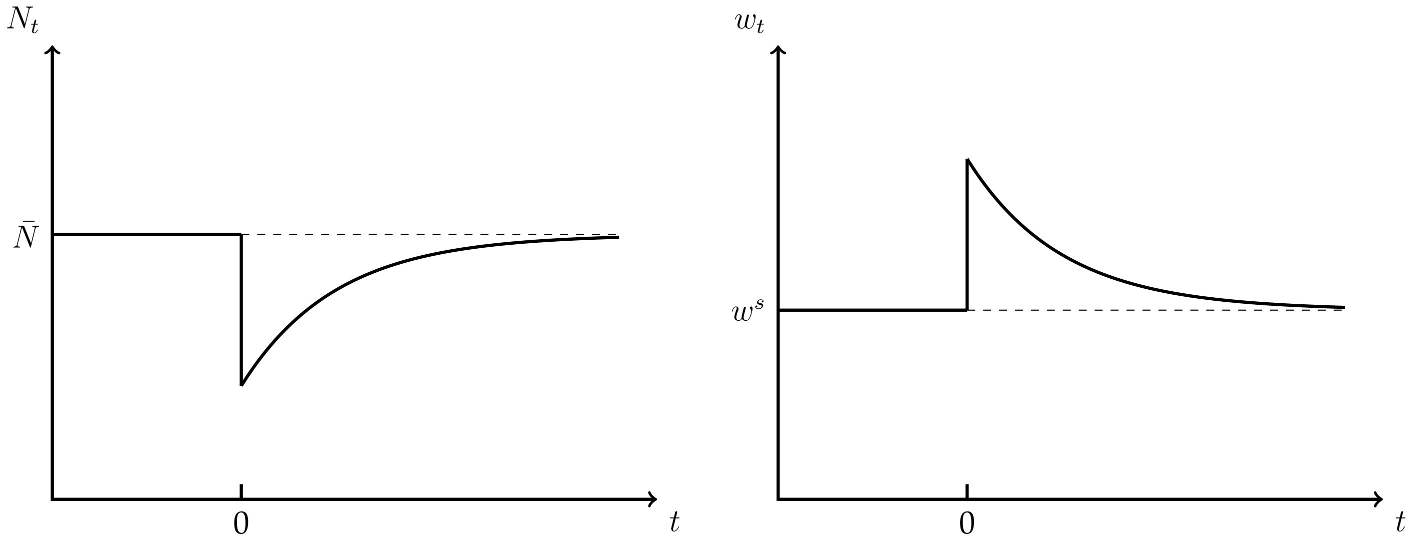

Figure 7: The Response of the Population and Real Wages to a Plague

logical improvements such as those mentioned above over many centuries did not raise standards of living substantially above subsistence.

Our analysis of the Malthus model up until this point has assumed for simplicity that the level of technology was constant at $A_t = 1$. Let's now consider instead what happens in a Malthusian economy in response to a one-time improvement in technology (e.g., the invention of a better plow). Figure 8 presents the population growth figure and the labor demand figure for this case. We suppose that the economy starts off at the steady state for a level of technology $A_t = 1$ with population at $\bar{N}$ and wages at w^s. This point is labeled A in both panels of figure 8. At time 0, the level of technology increases to $A_0 > 1$ and then stays constant at this higher level after this.

Looking back at the equations for population growth and labor demand—equations (8) and (7), respectively—we see that the level of technology appears in both of these equations. This means that a change in technology shifts both the population growth line and the labor demand curve. The particular way in which the level of technology appears in these equations implies that an increase in technology shifts both of these curves up. The labor demand curve shifts up because better technology implies that real wages are higher for any given level of population. The population growth line shifts up because the increase in real wages at a given level of the population implies that fertility net of mortality will be higher for that level of population and therefore next period's population will be higher. These shifts imply that the economy moves from point A in Figure 8 to point B, when the level

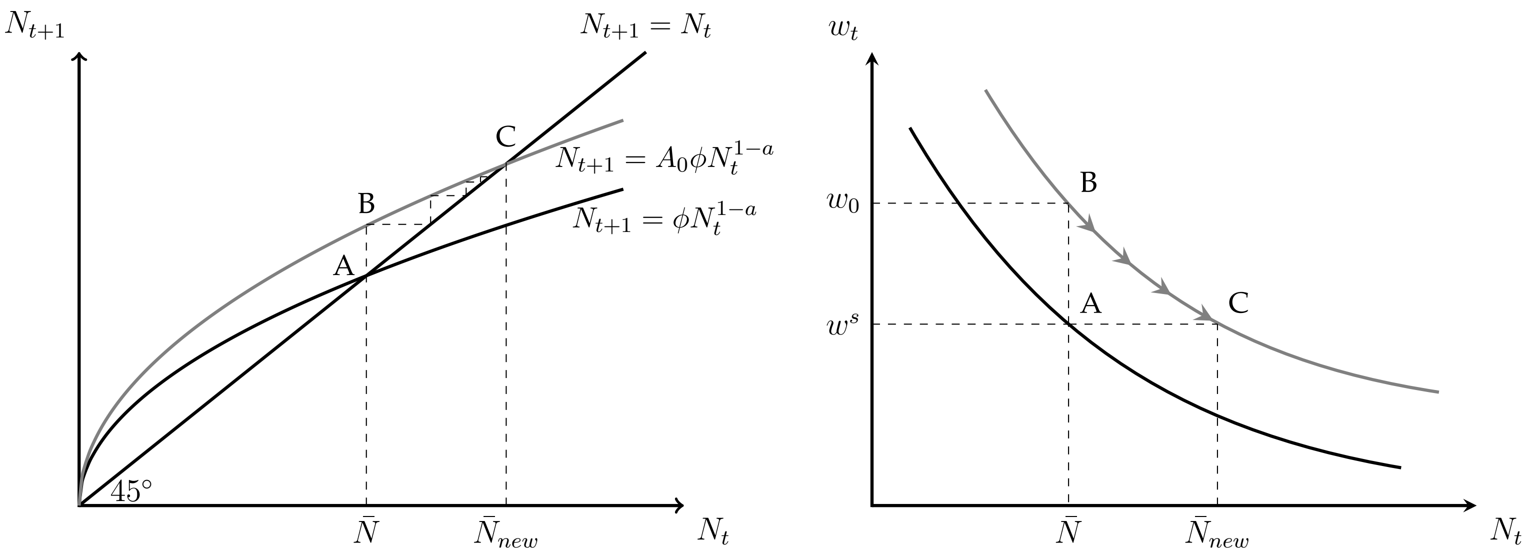

Figure 8: The Consequences of an Improvement in Technology

of technology increases.

Since point B is above the $N_{t+1} = N_t$ line in the population growth figure, the population starts growing. Just as in our earlier examples, the population will continue to grow until it reaches the point where the new population growth line crosses the $N_{t+1} = N_t$ line (point C in the figure). The population will therefore gradually grow from $\bar{N}$ to $\bar{N}_{new}$ in response to the increase in technology. $\bar{N}_{new}$ is the new steady state level of the population when the level of technology is A_0.

The response of real wages is quite different from the response of the population. When the level of technology rises, real wages jump up (the economy moves from point A to point B in the right panel of Figure 8). But then as the population grows, the marginal product of labor falls. This implies that real wages fall. In the labor demand figure, this process involves the economy moving along the new labor demand curve from point B to point C. Since the population keeps growing in the Malthus model while real wages are above subsistence, we know that real wages will fall all the way back to subsistence after the increase in technology.

This example shows how the Malthus model can provide an explanation for why real wages remained stuck close to subsistence levels prior to the Industrial Revolution even though substantial improvements in technology accumulated over time. The key reason why real wages remain unchanged in the long run in the Malthus model even when technology occasionally improves is that the population increases in response to improvements in technology. The response of the population gradu-

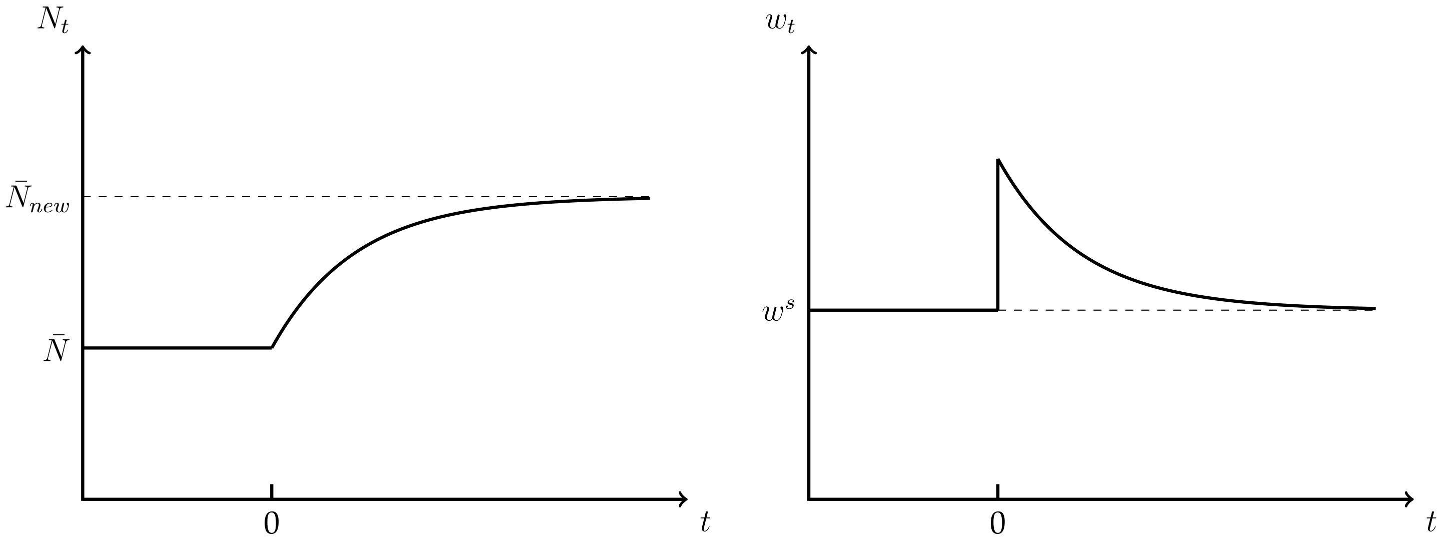

Figure 9: The Response of the Population and Real Wages to an Improvement in Technology

ally pushes the marginal product of labor back down to subsistence. In the long run, increases in technology therefore only result in a larger population, not in higher living standard.

Figure 9 plots time series plots of the response of the population and real wages to an increase in the level of technology. The real wage jumps up at the time of the increase in technology and then falls back down to its subsistence level. In contrast, the population rises gradually up to a new higher steady state level. The population reacts gradually because it takes time for the existing population to have children and for those children to grow up and have more children. Variables that have this slow moving property are called *stock variable*. There is a stock of people that exist at any given point in time, and it takes time to change the size of this stock. Stock variables react gradually to most shocks, but not all shocks. In particular, it is sometimes possible for a stock variable to decrease rapidly. In the case of the population, plagues and wars are examples of events that can lead to a very rapid fall in the population.

In contrast to the population, we are modeling the real wage as responding rapidly to all shocks. For simplicity, we are assuming that there are no reasons why this period's real wage is related to last period's real wage. Each period, the real wage moves to a point where labor demand equals labor supply. For example, when the level of technology increases, the real wage "jumps up." Variables that behave like this are called *flow variables*. The real wage is a payment for services rendered in a particular period. These payments can be dialed up or down at will, just like the flow of water into a bathtub can be dialed up or down at will. In contrast, the level of water in the bathub takes time to change, it is a stock variable.

Whether real wages should be modeled as fast moving or slow moving is a contentious matter in economics. There is considerable evidence that wages in fact are somewhat "sticky." The wages of many people are not set in competitive markets, but rather bargained or influenced by various norms. These aspects of wage setting can lead wages to react slowly to changes in the environment. Here we ignore this fact to keep the analysis simple. We will discuss price and wage stickiness in more detail when we cover monetary economics in chapters XX through XX.

An important difference between the change in technology analyzed in this subsection and the plague analyzed in the previous subsection is that we thought of the change in technology as being permanent, while the plague was a transitory event. This implied that the change in technology shifted the population growth and labor demand lines permanently and the economy moved to a new steady state with a higher level of population. In contrast, the plague only shifted the population growth line temporarily and the economy therefore returned to the old steady state after the plague had passed.

4 Growth Before 1500

At the beginning of this chapter, we used data on real wages and real GDP per person in England from 1250 to 1860 to assess the rate of "growth" in England prior to the Industrial Revolution (see Figure 2). The fact that real wages were almost identical in 1750 as in 1250 suggested very little improvement in the well-being of ordinary workers over this 500 year period. The data on real GDP per person, on the other hand, suggested steady growth over this period. We then discussed several reasons why it is difficult to reach firm conclusions about growth prior to the Industrial Revolution using the data in Figure 2.

One difficulty is that "growth" can mean several different things. Do we mean growth in individual income and well-being, or growth in GDP per person, or growth in productivity? The Malthus model we studied in section 3 highlights very starkly how these different concepts of growth can differ. In the Malthus model, an increase in productivity does not lead to an improvement in real wages in the long run. Productivity can therefore grow over time without this leading to an improvement in individual income and well-being. In the long run, an increase in productivity leads to an increase in the population in the Malthus model, not an increase in real wages.[5]

This insight suggests a different approach to assessing growth in productivity over time. According to the Malthus model, growth in population is an indirect measure of growth in productivity. Data on population over time can therefore be used to indirectly assess the growth rate of productivity. To see this, consider the population growth equation in the Malthus model (equation (8)) at two different times t and $t+1$. For simplicity, assume that there are no plagues (i.e., $\xi_t = 1$ for all t). Divide the time $t+1$ version of the equation by the time t version to get:

$$\frac{N_{t+1}}{N_t} = \frac{A_t}{A_{t-1}} \left(\frac{N_t}{N_{t-1}} \right)^{1-a}.$$

Take logarithms of this equation to get

$$\log \left(\frac{N_{t+1}}{N_t} \right) = \log \left(\frac{A_t}{A_{t-1}} \right) + (1-a) \log \left(\frac{N_t}{N_{t-1}} \right).$$

Recall that up to a first order approximation $\log(1+x) = x$. This means that up to a first order approximation $\log(N_{t+1}/N_t) = N_{t+1}/N_t - 1 = (N_{t+1} - N_t)/N_t \equiv g_{Nt+1}$. In other words, up to a first order approximation $\log(N_{t+1}/N_t)$ is equal to the growth rate of N_{t+1}, which we denote g_{Nt+1}. The same is true of productivity growth. We can therefore rewrite the last equation as

$$g_{Nt+1} = g_{At} + (1-a) g_{Nt}$$

up to a first order approximation. Finally, let's assume that growth in productivity is constant at g_A and solve for the steady state growth rate of the population. In a steady state, the growth rate of the population is constant ($g_{Nt+1} = g_{Nt} = g_N$) and the last equation simplifies to

$$g_A = a g_N. \tag{11}$$

This equation tells us that in a steady state with constant growth of productivity in the Malthus model, the growth rate of the population will be proportional to growth rate of productivity. The ratio of proportionality is a, which takes a value between zero and one. In other words, the growth rate of the population is an upper bound for the growth rate of productivity.

Table 1 reports estimates of the world population from 1,000,000 BCE to 1500 CE. While these estimates—especially those long before the current era—must be

Table 1: World Population from 1,000,000 BCE to 1500 CE

Year	Population	Growth Rate
-1,000,000	0.125	–
-300,000	1	0.000003
-25,000	3.34	0.000004
-10,000	4	0.00003
-5,000	5	0.00005
-1,000	50	0.0006
1	170	0.001
600	200	0.0003
1000	265	0.0007
1200	360	0.002
1500	425	0.0006

Note: Population estimates are reported in millions. The rightmost column reports annual population growth rates from $t-1$ to t. Population data are from Kremer (1993) Table I. Kremer's sources are Deevey (1960) for 1,000,000 BCE to 25,000 BCE and McEvedy and Jones (1978) from 10,000 onward. However, the growth rate estimate from 25,000 BCE to 10,000 BCE uses Deevey's population estimate for 10,000 BCE so as not to use numbers from two different sources to construct a growth rate estimate.

viewed as quite uncertain, they give us a rough sense of the rate of growth of the human population ever since our species evolved. It is clear from these estimates that the growth rate of the human population has been very small throughout history until 1500 CE. The largest growth rate estimate in the table is 0.002, or 0.2% per year. Most estimates are smaller than 0.1% per year and the estimates prior to 5,000 BCE are smaller than 0.01% per year. Viewed through the lens of the Malthus model, the population history of our species suggests that productivity growth was very small prior to 1500 CE.

5 Explaining Real Wages in England from 1250 to 1860

Let's look back at Figure 1. If we focus on the period before 1800, there are two striking facts that emerge from this figure. First, real wages in England rose very little if at all over this period; they were at a similar level in 1750 as they were 500 years earlier. Second, real wages fluctuated substantially over this period. They roughly doubled between 1340 and 1440, before falling slowly back to a much lower level.

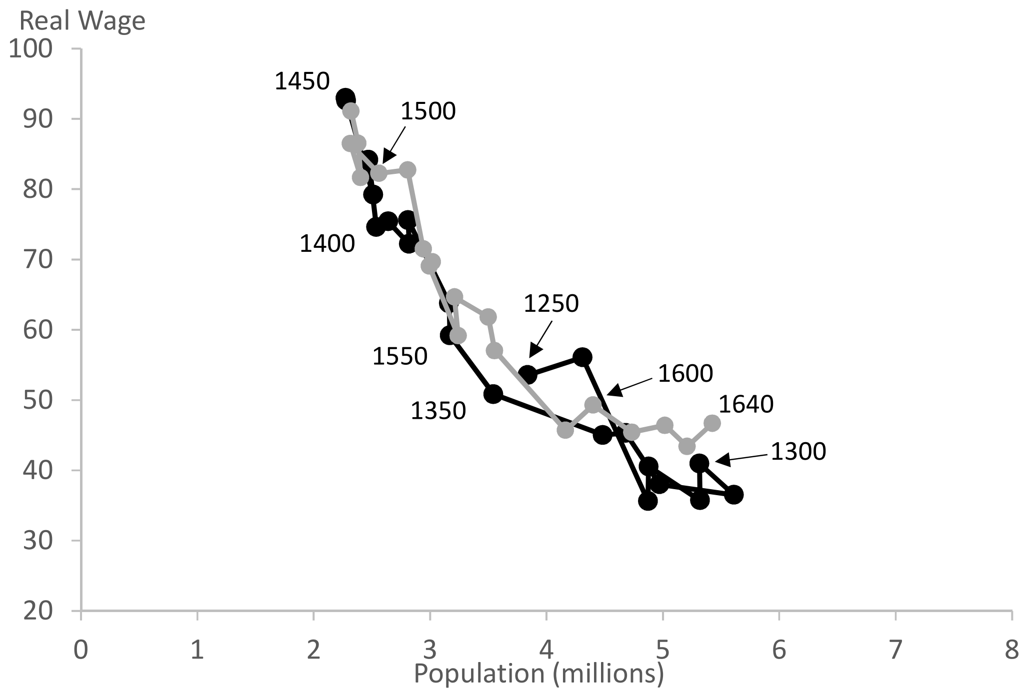

Figure 10: Real Wages and Population in England from 1250 to 1640

Note: The data from 1250 to 1450 are in black. The data from 1450 to 1640 are in grey. The real wage and population series are from Clark (2010). The real wage series is an index scaled to be equal to 100 in the 1860s.

5.1 The Link Between Population and Real Wages

The Malthus model suggests that the underlying causes of these fluctuations in real wages may be changes in the population in England over this period. Figure 10 plots the evolution of real wages and the population in England over the period 1250 to 1640 with the population on the x-axis and real wages on the y-axis. Each point on this figure gives the population and real wages in England at a given point in time.

The evolution of the economy from 1250 to 1450 is plotted in black in the figure. This shows a tight negative relationship between the population and real wages. From 1250 to 1300, the population rose from about 4 million to a little more than 5 million. Over this period real wages fell by roughly 25%. Around 1300, the population, however, started to fall. It fell very sharply in the 1340s as a result of the Black Death and continued to fall for the next 100 years as plagues continued to ravage England. Cumulatively, the population fell by roughly 60% over this 150 year period. Over this same period, real wages in England more than doubled.

The evolution of the economy from 1450 to 1640 is plotted in grey in the figure.

Again, there is a tight negative relationship between the population and real wages. Over this 200 year period, the population rose steadily as England slowly recovered from the plagues of the preceding century. At the same time, real wages in England fell steadily. By 1640, both the population and real wages in England were back to almost exactly the same point as they were at in 1300.

This type of negative relationship between real wages and the population is exactly what the Malthus model predicts in a world with no technological growth. To see this, look back at Figure 5. It plots a negatively sloped labor demand curve. The data in Figure 10 seem to indicate that the English economy moved up and down along such a labor demand curve in response to the plagues that ravaged England in the late Middle Ages.

The evolution of real wages and the population in England over the period 1250 to 1640, thus, constitute an impressive empirical success for the Malthus model. The large increase and then subsequent decrease in real wages between 1300 and 1640 may have seemed odd when you first studied Figure 1: Why would real wages fall by such a large amount over a two hundred year period? But now we have an explanation for this: The population more than doubled over this period pushing down real wages.

5.2 The European Marriage Pattern

Why did it take so long (300 years) for the English population to recover after the Black Death? One reason is that the Black Death was not the only plague to hit England. England was hit by a wave of plagues during the 14th to 17th centuries, each of which slowed down the recovery of the population. This was however likely not the only reason. A second reason is that these plagues may have substantially reduced fertility in England by changing marriage patterns. Around the time of the Black Death, a distinct "European Marriage Pattern" emerged in Western Europe where the average age of marriage for women rose from about 20 years to about 25 years and a significant fraction of women never married (Hajnal, 1965). Together these changes allowed Western Europeans to avoid roughly one-third of all possible births and substantially slowed down the recovery of the population.

The economic historians Nico Voigtländer and Hans-Joachim Voth have proposed an interesting theory for how the Black Death may have caused the European Marriage Pattern to emerge (Voigtländer and Voth, 2013b). They argue that the increase in real wages relative to the cost of land that occurred in the wake of the Black Death led to a shift away from grain farming and towards livestock and dairy farming, which women had a comparative advantage in. This improved the employment options of women and led them to marry later. Related ideas of "girl power" are developed in De Moor and van Zanden (2010).

To support their theory, Voigtländer and Voth present evidence that there was indeed a large shift towards pastoral farming in England after the Black Death and that the age of first marriage was higher in regions with a large amount of pastoral farming. Finally, they argue that since Northwestern Europe was better suited to pastoral farming than Southern and Eastern Europe (or China), the shift towards pastoral farming was more pronounced in Northwestern Europe. This implied that the population rebounded more slowly in Northwestern Europe after the Black Death and real wages remained high for a longer period.

5.3 Technological Growth in England from 1250-1860

There is a second important lesson to be learned from the data in Figure 10. This is that there seems to have been virtually no technological growth in England over the period 1250 to 1640. Recall that technological growth shifts the labor demand curve out. The data in Figure 10 point to no such shifts having occurred between 1250 and 1640. How can we conclude this? The easiest way to see this is to notice that the English economy was in virtually the same location on the figure in 1640 as in 1250. If the labor demand curve had shifted, this could not have been the case, since the point that the economy was at in 1250 would no longer be on the curve in 1640 (it would be below and behind the new curve). The fact that the English economy returned to virtually the same point after a 400 year plague-induced ride up and down the labor demand curve means that the labor demand curve couldn't have shifted by any appreciable amount over this 400 year period.

Our earlier discussion at the beginning of this chapter as to whether there was growth in the income of laborers in England before the Industrial Revolution was based on looking at Figure 1. It is hard to tell from Figure 1 whether there was slow underlying trend growth. The large fluctuations imply that it is hard to know exactly what the underlying trend was. Informally, one can draw various plausible "trend lines" for the real wage series in Figure 1 for the period 1250 to 1750. Based on that figure one therefore cannot reject the notion that there was slow positive trend growth in real wages.

By bringing in data on the population, Figure 10 helps us sharpen our inference about this issue. It shows that one can explain the large fluctuations in real wages over this period by plague-induced variation in the population. And it shows that what is left over after one does this is essentially no growth (i.e., no shifts in the labor demand curve). In this way, we are able to make much more precise inference about the underlying growth rate of wages of laborers in England before 1640 than is possible if one only looks at data on real wages (Figure 1).

It is sometimes argued that modern economic growth of the order of one to two percent per year can't possibly have started much before 1800 because real wages were quite close to subsistence at that point. If one were to backcast one to two percent changes in real wages before 1800—the argument goes—one would very quickly hit subsistence. However, the Malthus model makes clear that this argument is flawed if the type of growth one has in mind is growth in productivity. The reason is that changes in productivity don't necessarily translate into changes in real wages in a Malthusian economy. Rather, it is the size of the population that changes as productivity changes. Through the lens of the Malthus model, it is therefore important to have data on the evolution of the population over time to make inference about whether productivity was growing before 1800. The evidence we discuss above that the labor demand curve in England was stable over the period 1250 to 1640 is much stronger evidence for lack of productivity growth than anything that can be inferred from real wage data alone.

Consider next Figure 11. This figure extends the data plotted in Figure 10 forward to 1860. Clearly, something very important changed in England around 1650. The point for 1650 is way off the previous negative relationship between population and real wages. After 1650, the points continue to move further and further away from this earlier relationship. From 1640 to about 1730, the points move mostly up in the figure, implying that real wages are increasing while the population is relatively stable. One reason for the lack of population growth during this period is plagues. For example, a massive plague outbreak occurred in London in 1665-1666, which is commonly referred to as the Great Plague of London. Then between 1730 and 1800 the points move mostly to the right, implying that real wages are stable, while the population grows. Around 1800, however, a huge acceleration occurs and the points start flying up and to the right at a rate that is much faster than any movements prior to this.

The fact that the English economy clearly moved off the previous negative relationship between real wages and population around 1650, is strong evidence that productivity growth of some form began in England at this time. The timing of this

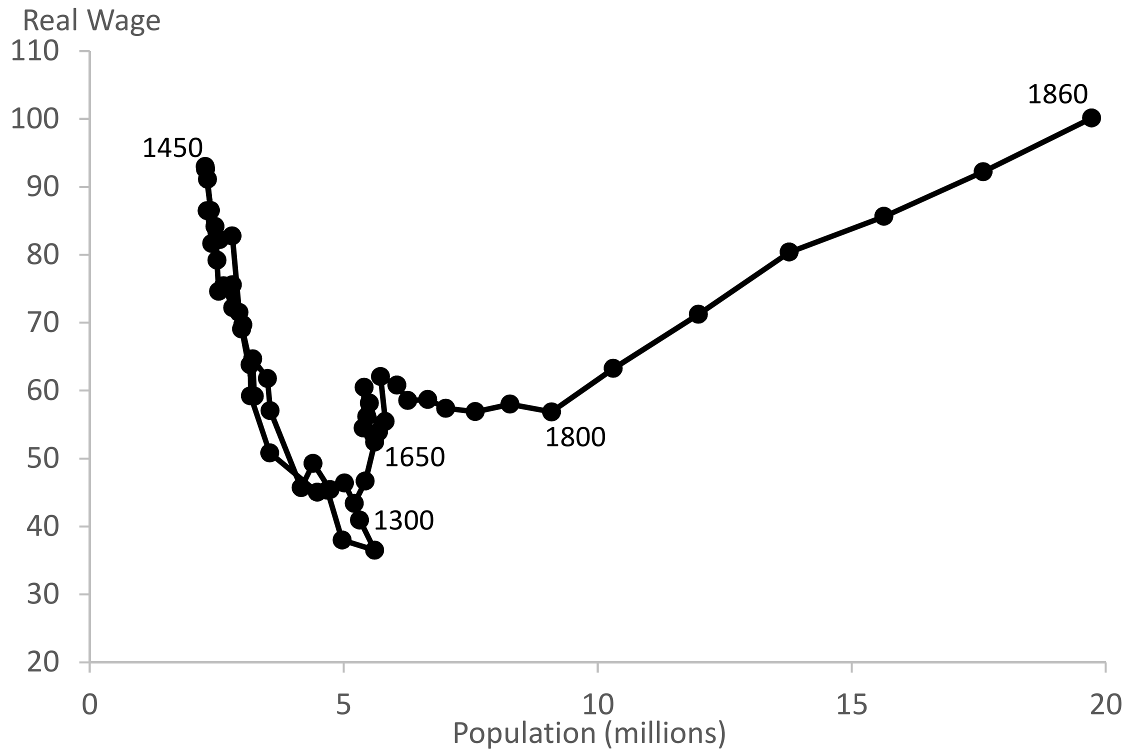

Figure 11: Real Wages and Population in England from 1300 to 1860

Note: This figure replicates Figure 5 in Clark (2005). The real wage and population series are updated series from Clark (2010). The real wage series is an index scaled to be equal to 100 in the 1860s.

change is very intriguing since England underwent a major political upheaval starting in the 1640s. The period from 1642 to 1651 is referred to as the English Civil War period as forces aligned with Parliament in England overthrew the monarchy and set up a Commonwealth. It is perhaps particularly surprising that the first major signs of increased productivity in England (at least from the perspective of ordinary laborers) occur during a time of armed conflict in England. Something that may explain this is that this was also a period of major institutional change. We will discuss the idea that changes in institutions in England in the second half of the 17th century may have played an important role in igniting growth in productivity in more detail in chapter XX [Industrial Revolution Chapter].

The large increase in technological growth—i.e., the speed with which the points in Figure 11 shift out and up—that occurs around 1800 is quite striking. Economic historians have long debated whether it is appropriate to refer to the Industrial Revolution as a revolution. Many have argued that the process that led to the emergence of modern growth was more of an evolutionary process than a revolutionary process. The data for the period 1640 to 1800 does support the notion of a long transition period. But the word revolution seems appropriate as a description of the sharp increase in productivity growth that is so obvious and striking in Figure 11 right after 1800. Something dramatic and revolutionary did seem to occur in Britain around 1800. Referring to this as the Industrial Revolution seems fitting.

6 Malthus' Unfortunate Timing

Thomas Malthus sometimes gets a bad rap. He predicted that real wages were doomed to remain close to subsistence. This has obviously not turned out to be correct. To the contrary, real wages of laborers have risen by roughly 1500% since his writing. For this reason, it is easy to make fun of Malthus. But another, more positive, way to view Malthus' contribution to knowledge is that he proposed a model that helps explain all of human history except for the last 200 years. As we have seen in this chapter, Malthus' model is very helpful in explaining the evolution of real wages in England from 1250 to about 1800. Viewed in this way, Malthus' contribution seems quite impressive.

Clearly, however, Malthus' timing was unfortunate. Figure 12 shows how his prediction that real wages would never grow in a sustained way was true up until the point of his writing, but not after that point. Malthus' *Essay* was first published in 1798. It was exactly around 1800 when real wages in England started growing in a sustained way.

What changed so as to make Malthus so wrong about the future even though he had been quite correct about the past? One important change was a large increase in the pace of productivity growth. This is evident from Figure 11. Productivity growth jumped up around 1800 in Britain and stayed at a higher level going forward. This alone may have been enough to give rise to sustained growth in real wages. Whether this is the case depends on the strength of the Malthusian forces that push wages back down towards subsistence. Figure 11 makes clear that the increases in real wages that occurred from 1800 to 1860 coincided with quite substantial increases in the population. This shows that the Malthusian population dynamics were still operating during this period, i.e., higher real wages seemed to be leading to substantial increases in the population. However, these increases in the population were evidently not large enough to push real wages down to subsistence. Perhaps productivity growth was simply high enough after 1800 that it

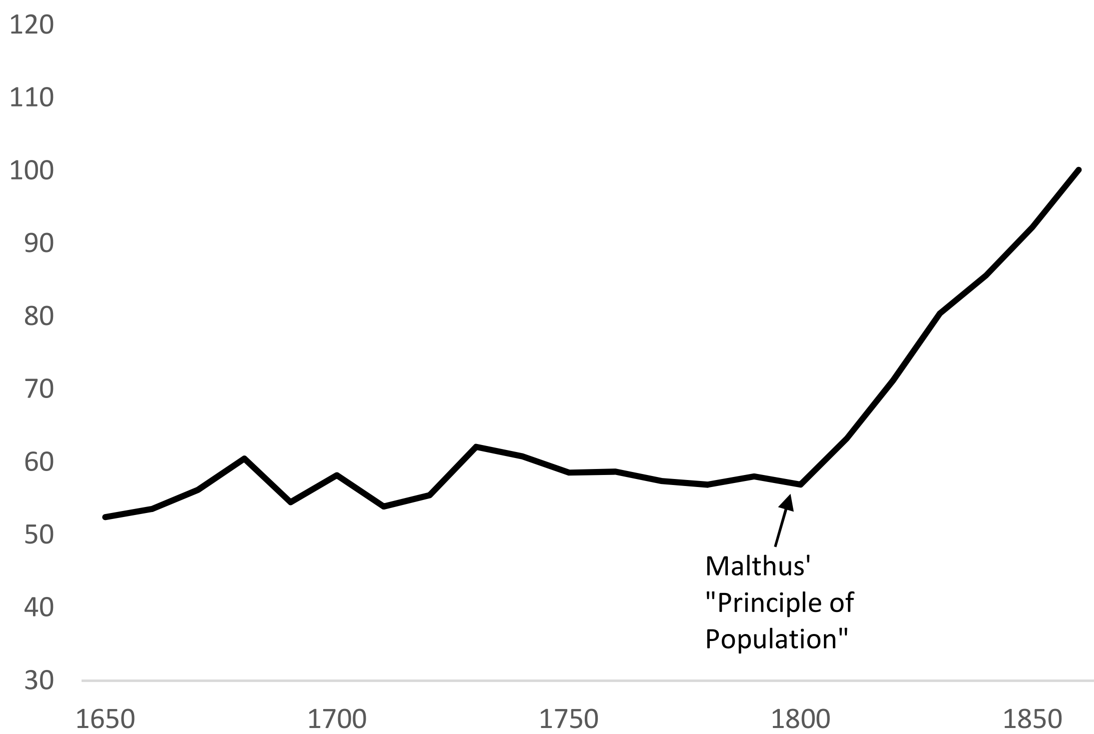

Figure 12: Real Wages in England from 1650 to 1860

Note: The real wage series is from Clark (2010). It is an index scaled to be equal to 100 in the 1860s.

overwhelmed the Malthusian forces.

A second reason why Malthus' theory broke down after 1800 is that land progressively became less important as a factor of production. Recall that Malthus' theory relies on the existence of a fixed factor of production. The existence of this fixed factor implies that the marginal product of other factors—e.g., labor—falls as these factors become more plentiful. Land is the most obvious fixed factor. The advent of steam power in the late 18th and early 19th centuries was a colossal change in this regard. Before steam power, the production of usable energy—a crucial input in most production—relied heavily on animal power, human power, and firewood, all of which require large amounts of land to produce. Steam power allowed the substitution of machines run on fossil fuels for these other sources of energy. This greatly reduced the importance of land in production. In addition to this, increases in agricultural productivity together with the fact that people choose to spend a smaller and smaller fraction of their income on food as they become richer (i.e., food is a necessity), have greatly reduced the role of land in overall production.

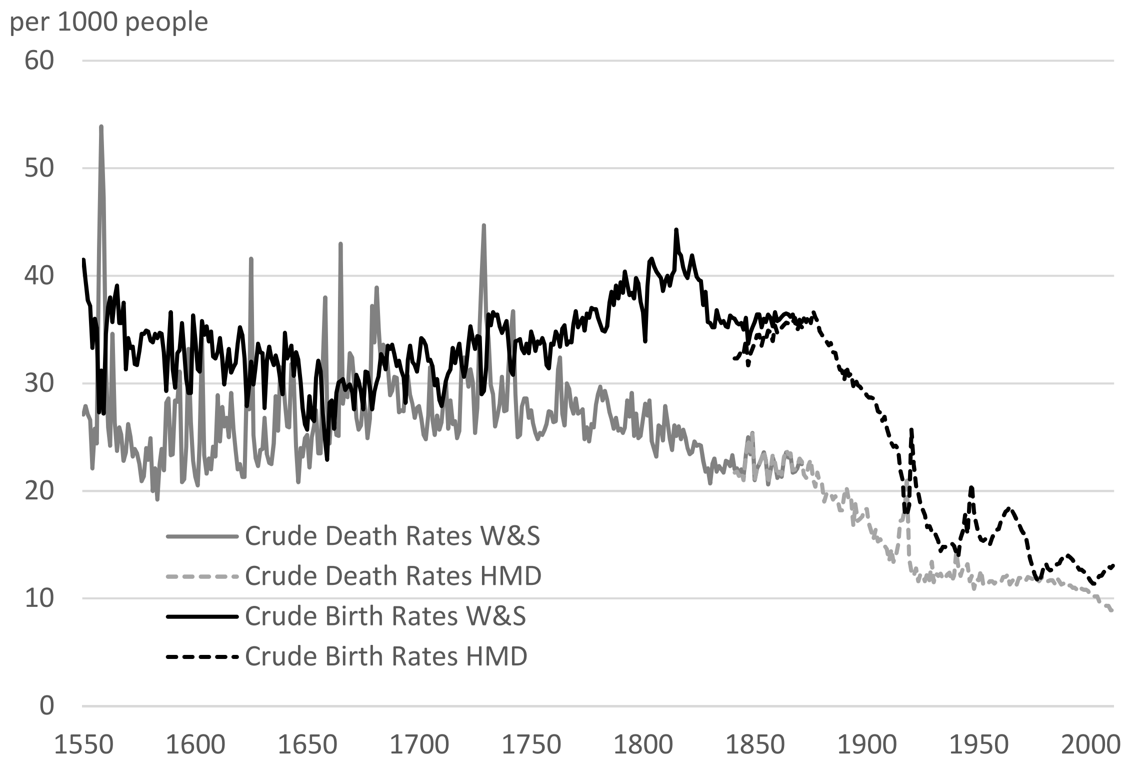

Figure 13: Birth and Death Rates in England from 1550 to 2010

Note: Crude birth and death rates from Wrigley and Schofield (1981) are plotted for 1550-1871. Crude birth and death rates from the Human Mortality Database are plotted for 1841-2010. Crude birth and death rates are births and deaths in a particular year divided by the population in that year.

6.1 The Demographic Transition

A third reason why Malthus' theory broke down is that the relationship between real wages and population growth changed. Figure 13 plots estimates of annual crude birth and death rates in England from 1550 to 2010. The crude birth rate is defined as the number of births in a year divided by the population in that year. Analogously, the crude death rate is defined as the number of deaths in a year divided by the population in that year. These rates are crude because they don't adjust in any way for the age distribution of the population. Figure 13 combines estimates from two sources: Wrigley and Schofield (1981) and the Human Mortality Database. Fortunately, there is a short period of overlap between these two sources in the mid-19th centuries and they agree almost exactly during this period. Wrigley and Schofield base their estimates mainly on baptism and burial records.

Up until about 1825, the data on birth and death rates in Figure 13 support

Malthus' theory quite well. Malthus' theory predicts that birth rates should rise and death rates should fall when real wages increase (and the opposite should occur when real wages decrease). From 1550 to about 1650, birth rates are trending downward and death rates are trending upwards. From about 1650 to about 1825, birth rates are trending upward and death rates are trending downwards. This lines up well with changes in real wages. Recall that real wages generally fell from 1550 to 1640 and rose after this point (Figures 10 and 11).

The extremely high volatility of birth and especially death rates before 1750 makes it somewhat difficult to see the trends in birth and death rates in Figure 13. To make it easier to see these trends, Figure 14 plots centered 11-year moving-averages of the birth rate and death rate in England from 1550 to 2005. A centered 11-year moving-average of the birth rate for a particular year is the average of the birth rate in that year and the birth rates in the five preceding and five subsequent years. Averaging over 11 years smooths out the series considerably and thereby makes the longer-term trends more visible.

Malthus' theory predicts that as real wages kept rising after 1800, birth rates should have kept rising and death rate falling. While this occurred for some time, it started to break down in the case of birth rates around 1825. First, birth rates fell slightly. Then they remained stable for about 50 years. Finally, around 1880, they started falling again. This time, the fall was enormous. By 1930, the birth rate in England had fallen to 15 per 1000 people from 35 per 1000 people 50 years earlier.

A result of this huge fall in birth rates has been that the relationship between real wages and population growth has dramatically changed. High real wages are no longer associated with high population growth. Real wages in England grew by over 400% in the 20th century, but native population growth slowed considerably. Obviously, Malthus's theory of population growth is no longer an accurate theory for England.

The pattern for birth rates and death rates that we see in Figures 13 and 14 for England is called the *demographic transition*. This same pattern has been observed in many other countries over the past 200 years. It seems to be a universal law of economic development: Poor countries have high birth and death rates. Increases in real wages, initially, lead to a reduction in death rates and an increase in birth rates. During this phase, population growth is rapid. As real wages keep rising, there comes a point when birth rates stop rising and then start falling. Birth rates fall fast enough that the gap between the birth rate and the death rate closes and population growth slows. Eventually, death rates stabilize at much lower levels. In some cases,

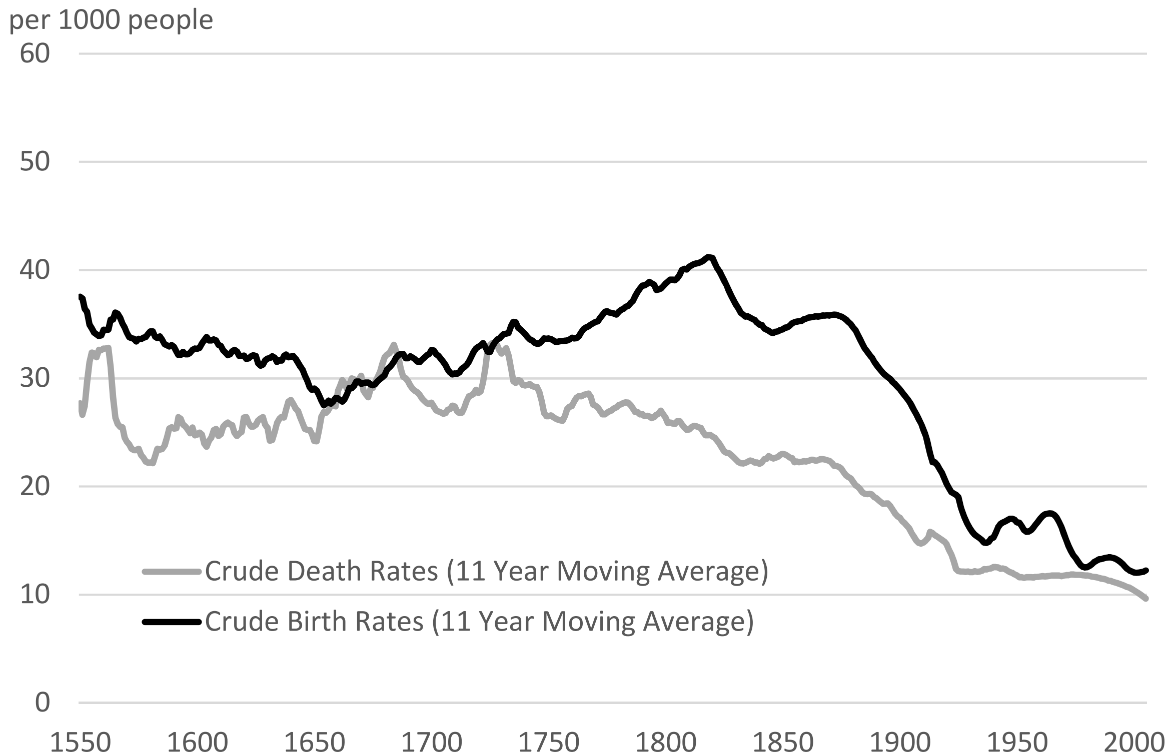

Figure 14: Smoothed Birth and Death Rates in England from 1550 to 2005

Note: The figure plots 11-year centered moving averages of crude birth and death rates for 1550-2005. The data used to construct the moving averages are the same as are plotted in figure 13. For the years with data both from Wrigley and Schofield (1981) and Human Mortality Database I have used a simple average of the values from the two sources.

birth rates stabilize at a similar level or slightly higher level than death rates. This is the case, for example, in England and the United States. In other cases, however, birth rates fall below death rates and the native population starts shrinking. This is the case, for example, in Germany and Japan.

It is easy to identify several important contributing factors to the huge decrease in death rates between 1750 and 1950. Improvements in sanitation including clean running water and covered sewer systems in urban areas no doubt played a major role in improving health. Large reductions in the price of cotton clothing (underwear) and soap meant that commoners could improve their personal hygiene. Better transportation infrastructure and more generous poor relief lowered the incidence of famines and disease outbreaks. The development of convincing empirical evidence in favor of the germ theory of disease in the 19th century by Ignaz Semmelweis, Joseph Lister, John Snow, Louis Pasteur, Robert Koch, and others dramatically lowered rates of infection and profoundly affected public policy regarding diseases such as cholera. The invention of the smallpox vaccine by Edward Jenner in 1796 was important. In the 20th century, the discovery of the antibiotic properties of penicillin by Alexander Flemming is but one of many major advanced in medicine contributing to lower death rates.

The large drop in birth rates between 1880 and 1930 is more mysterious. One factor that almost certainly played an important role was the increased quality of contraceptive methods. The spread of effective methods of contraception allowed couples to control their fertility without having to resort to abstinence. Other proposed ideas for why birth rates fell as much as they did are more speculative. An important idea is the trade-off between quantity and "quality" of children (Becker, 1960; Becker and Lewis, 1973). When income rises, couples spend more on children. However, there are two distinct ways in which couples can spend more on children. One is to have more children (i.e., increase the quantity of children). The other is to invest more in each child (i.e., increase the "quality" of their children). One possible explanation for the large reductions in fertility is that the process of development lead to a large shift away from quantity and towards quality when it comes to children. One possible reason for such a shift is the idea that the returns to education may have risen sharply as England industrialized. Galor (2005) emphasizes the idea that industrialization lead to a huge increase in the demand for skilled labor in the late 19th century and early 20th century in Europe. Another possible explanation for the fall in fertility is women's empowerment. The burden of caring for children has fallen very disproportionately on women (not to mention the burden of *having* the children and the risks of dying in childbirth). It may be that improved education of women and other developments that improved womens' bargaining positions within the marriage may have resulted in lower fertility.[6]

7 The Dismal Science: Malthus and Economic Policy

Malthus wrote his famous essay as a response to the writings of optimistic social thinkers of the time such as the English radical William Goodwin and the French thinker Condorcet. These thinkers attributed much social evil to unjust laws and institutions and imagined a future of prosperity for all once these unjust laws and institutions had been modified appropriately. Malthus was skeptical of this line of thinking. He argued that the types of policies that Goodwin and others argued for might actually have the perverse effect of accentuating social evils such as poverty.

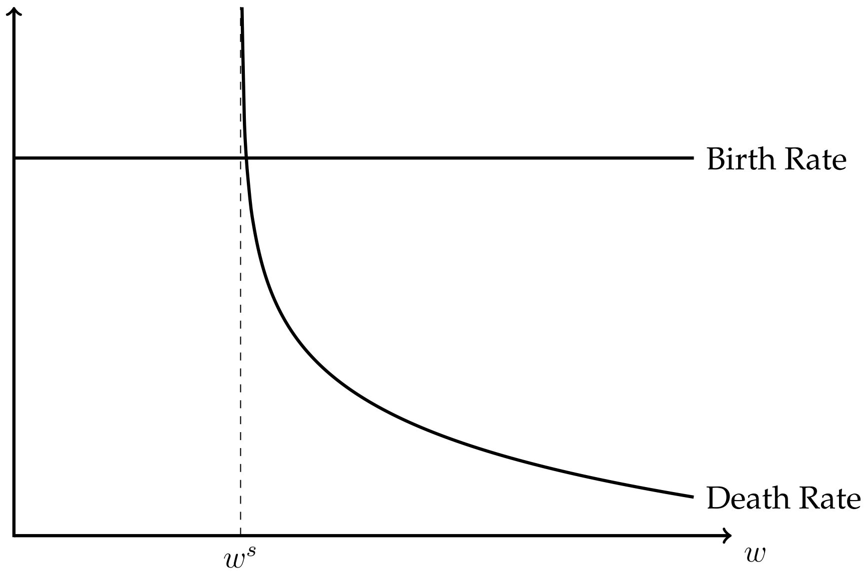

Figure 15: A Simplistic Model of Birth and Death Rates

Malthus was particularly critical of the English Poor Laws. The Old Poor Law was passed in 1601 and required local parishes to provide assistance to the poor and needy financed by local taxes on property owners. Malthus argued that "though they may have alleviated a little the intensity of individual misfortune, they have spread the general evil over a much larger surface" (Malthus 1798, chapter 5). The reason for this is that he believed that the Poor Law weakened natural checks on population growth, led to a larger population, and bid down wages. The end result was a larger population of people that were equally poor or perhaps even poorer. This "Malthusian" argument against poor relief gained influence in England after the publication of Malthus' essay. It played in important part in the political process that led to the passage of the Poor Law Amendment Act of 1834, which aimed to reduce the generosity of the English poor relief system. (Malthus advanced several other "conservative" arguments against poor relief, such as the idea that poor relief weakened incentives of the poor to work and save.)

Malthus' model of how the economy evolves over time has extremely depressing implications about public policy not only about poor relief but more generally. To understand this better, it is useful to develop more carefully the concept of subsistence wages. One way to use the term subsistence wage is as the level of wages below which no one can live at all. Suppose that the death rate rises without bound when wages approach some level w^s. Figure 15 plots a case like this. In this case, w^s

might be referred to as the subsistence wage. Suppose, furthermore, that the birth rate is constant as a function of wages (e.g., at their biological maximum level) and that its level is high enough that the death rate only reaches this level when real wages are very close to subsistence (as in Figure 15). In this case, the steady state wage rate in the economy will be very close to subsistence.

Suppose real wages are initially at a level higher than the subsistence wage. The birth rate is then higher than the death rate, which implies that the population will increase over time (consistent with equation (6)). As the population increases, real wages will fall—equation (7)—and the economy will move towards the left in Figure 15. The population will continue to increase and the real wage will continue to fall until the real wage has fallen to a point where the death rate and the birth rate are equal. At that point, the population reaches a steady state level since an equal number of people are born and die each period. This occurs very close to the subsistence wage level w^s in Figure 15.

This version of the Malthus model is overly simplistic in that we have abstracted away from what Malthus referred to as preventive checks. Preventive checks are factors that reduce birth rates below the biological maximum. These include contraception, delayed marriage, and regulation of the "passion between the sexes" within marriage, as Malthus referred to it. Clark (2007, chapter 4) discusses evidence on these preventive checks for various countries and time periods before 1800. He argues that the birth rates were generally far below their biological maximum, but that the importance of different preventive checks differed across countries and time.

Contraception was very rudimentary before 1800, and viewed as a moral vice by the Church and many in society (including Malthus). Clark discusses various pieces of evidence suggesting that contraception and conscious family planning more generally were not a significant preventive check prior to 1800. However, this conclusion is controversial. The main factors lowering birth rates in Northwestern Europe prior to 1800 were likely delayed marriage and the fact that a non-trivial fraction of women never married—i.e., the European Marriage Pattern discussed earlier in the chapter. These factors seem to have prevented roughly half of all potential births in Northwestern Europe after the Black Death. Marriage patterns in Europe contrast sharply with evidence from China, where virtually all women married and the average age of first marriage for women was only 19 years. The main factors lowering birth rates in China prior to 1800 seems to have been lower fertility within marriage and female infanticide. Low marital fertility in China is not well understood. Clark mentions several possible reasons including very low income, extended breast feed-

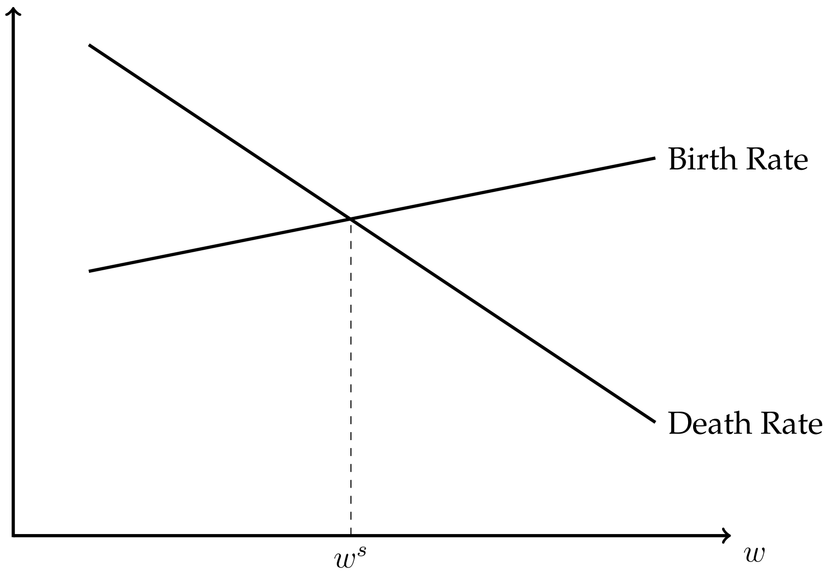

Figure 16: More Realistic Model of Birth and Death Rates

ing, and cultural beliefs that engaging in sex was damaging to health.

The preventive checks discussed above lower the birth rate at any given level of real wages—i.e., they shift the birth-rate curve in Figure 15 down. In addition, it is reasonable to believe that these preventive checks will be stronger when wages are low. This implies that the birth-rate curve shifts down more at lower real wage levels and becomes upward sloping. Figure 16 depicts the birth- and death-rate curves in this case, zooming in on the region around where the two curves cross. Notice that in Figure 16 we denote the real wage at which the birth- and death-rate curves cross by w^s. Here we have therefore shifted a bit the meaning of the subsistence wage. Now subsistence wage no longer refers to the lowest wage possible for survival. Rather, it refers simply to the wage rate at which population reaches a steady state (this is how we were using this term earlier in the chapter). Perhaps a more appropriate name for w^s would be steady-state real wage in this case. But we will continue to refer to it as the subsistence wage to be consistent with prior literature on this subject (e.g., Clark, 2007).

Armed with Figure 16, we are now ready to discuss the depressing policy implications of the Malthus model. The central policy implication of the Malthus model is that any public policy that doesn't shift the birth- or death-rate curves has no effect on the material well-being of the poor in the long run. This follows from the fact that the Malthus model has a unique steady state at which the real wage is w^s, and the only way to shift w^s is to shift either the birth-rate curve or the death-rate curve. In other words, the only way to improve material living standards of the bulk of the population in the Malthus model is to reduce birth rates or increase death rates.

Let's start by considering the case of redistribution towards the poor (the English Poor Law was an example of such a policy). At the time such a policy is instituted, it will raise the real income of the poor. We can think of this as an increase in the "after-transfer" wage for the poor. This policy will therefore shift the economy to the right in Figure 16. Higher income will raise the birth rate of the poor—e.g., by enabling poorer men to provide for a wife and children. Higher income will also reduce the death rate by improving nutrition and living conditions. The redistributive policy will therefore lead the population to start growing. The growth in the population will drive down real wages. This process will continue until after-transfer real wages have fallen all the way back to w^s. The long run effect of the redistributive policy will therefore not be to raise the material well-being of the poor. Rather, the policy will only increase the number of poor people in the long run.

It may even be the case that the redistributive policy will lower the material well-being of the poor in the long run. This is the case if the policy leads to a lower death rate at any given real wage rate—i.e., if it shifts the death-rate curve down. One reason why the redistributive policy may shift the death-rate curve down is that it will likely reduce the variance of real wages among the poor. Our simple model abstracts from heterogeneity among the poor. But in reality some among the poor in any given year will face particular hardship (lose their job, become ill, etc.). These people will face elevated death rates. If the redistributive policy disproportionately helps those among the poor that are particularly destitute at any given point in time (as any well-designed poor relief presumably does), the policy would likely shift down the death-rate curve by lowering the death rate of these particularly destitute people. The depressing implication of the Malthus model is that by doing this, the policy will lower the long-run average wage rate in the economy since the birth and death-rate curves will cross at a lower wage rate after the death-rate curve has shifted down. In other words, the policy will make the poor even poorer. This is depicted in Figure 17.

Let's next consider the opposite of a redistributive policy: a policy where the wealthy tax the poor (which was not uncommon before 1800). In the Malthus model, this policy will not reduce the material well-being of the poor in the long run. The response of the economy to this policy will be the exact opposite to that of the redistributive policy considered above. To begin with, the after-tax wages of the poor

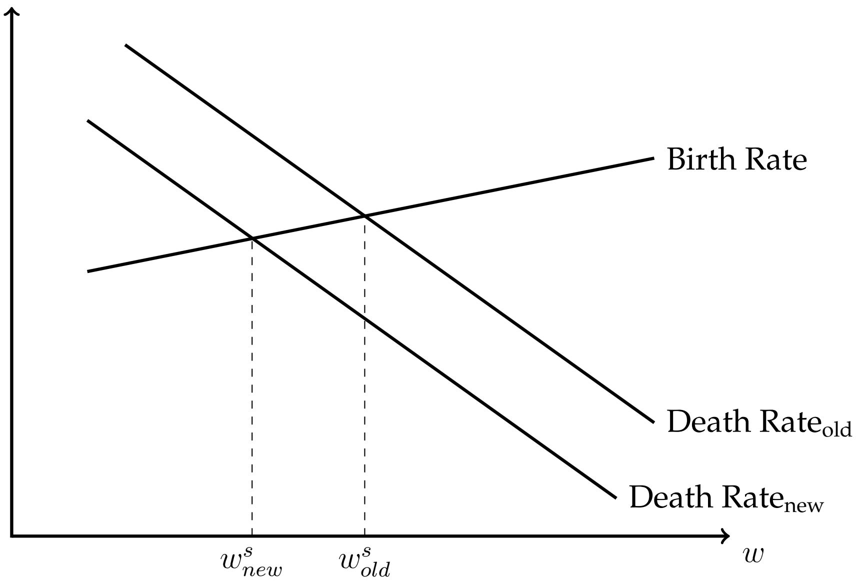

Figure 17: Effect of Shift in Death Rates

fall. This raises the death rate and lowers the birth rate of the poor. As a consequence, the population falls, which leads real wages to rise. The economy reaches a new steady state when the population has fallen enough that the after-tax real wage of the poor has risen all the way back to its original level. The long-run effects of this policy are therefore to enrich the ruling class and reduce the size of the lower class without reducing its material well-being.

Consider next the effects of an Industrious Revolution in the Malthus model: Suppose the poor suddenly start to work more hours per day or more days per year. In the short run, this will raise their income. But in the long run, the rise in real income will induce the population to grow until real income has fallen all the way back to its original level. The seemingly virtuous burst of industriousness among the working class, therefore, leaves them worse off in the long run: Their income is the same but they are working harder to attain this level of income. This logic leads Clark (2007) to argue that the Neolithic Revolution—in which humans took up settled agriculture instead of their prior hunter and gatherer lifestyle—led to a fall in welfare due to increased labor.

Finally, let's consider the effects of improvements in public health. The direct effect of improvements in public health are to reduce death rates at any given level of real wages—i.e., shift the death-rate curve down as in Figure 17. In a Malthusian economy, this policy leads the population to start growing and real wages to start falling. This process will continue until the real wage has fallen to a point where the new death-rate curve intersects the birth-rate curve. At this new steady state, real wages are lower than before. The long-run effect of an improvement in public health is therefore a society with a larger number of poorer people than before.

Whether an improvement in public health reduces welfare in the Malthus model is tricky and depends crucially on how we value an extra year of life. The policy leads each among the poor to be poorer than before, which is bad, but it leads them live longer, which presumably is good. In addition to this, there are more people as a result of the policy, each of which values being alive. In evaluating welfare, one must trade-off these positive and negative effects.

Evidence on real wages and adult height suggests that material well-being in Northwestern Europe was substantially higher than in China and Japan before 1800 (Clark, 2007). One likely contributing factor to this is the relative squalor of European living arrangements at the time. The filthy customs of Europeans probably contributed to higher death rates and therefore a higher subsistence real wage rate. East Asians were much cleaner and therefore probably had lower death rates at any given level of real wages resulting in a lower subsistence real wage rate. Another factor was the high incidence and intensity of warfare in Europe between 1400 and 1700 (Voigtländer and Voth, 2013a,c).

The last 300 years have seen a tremendous improvement in public health in the world. Many of these public health improvements have reached not only rich countries but also poor countries. Clark (2007) argues that these improvements in public health have contributed to the Great Divergence between rich and poor countries in the last 200 years. While some countries have escaped the Malthusian trap, others have not yet done so. These poor countries have actually become substantially poorer than 200 years ago because improvements in public health have lowered the subsistence wage by shifting down the death-rate curve in these countries. Before the advent of modern medicine and the germ theory disease, it was simply not possible to sustain a stable population at as low real wage rates as it today. According to this view, the 50 fold difference between the richest and poorest countries today is the result of a roughly 15-fold increase in real wages in the richest countries, a roughly two-fold difference between the richest and poorest countries in 1800, and a roughly two-fold decrease in real wages in the poorest countries of the world since 1800.

Notes

[1]The seminal work on the construction of real wages in England back to the 13th century was done by Phelps Brown and Hopkins (1955, 1956). Other important contributions include Lindert and Williamson (1983), Feinstein (1998) and Allen (2001, 2007).

[2]One important difference between Clark's real wage series and the real wage series of Feinstein (1998) and Allen (2007) is that Clark's series rises substantially more between the late-18th century and mid-19th century than do Feinstein's and Allen's. An important question that hinges on this difference is the extent to which labor gained from the Industrial Revolution in England. Recall that the *Communist Manifesto* was published in London in 1848 and claimed that the industrial proletarian class was not sharing in the gains from industrialization. Feinstein's and Allen's series support this notion more than Clark's does. Another issue is that Clark's series is lower and less volatile before 1800 than the series of Phelps Brown and Hopkins (1955, 1956)—in particular, the rise in real wages after the Black Death is smaller in Clark's series than Phelps Brown and Hopkins' series.

The differences in the real wage series constructed by these different scholars are almost entirely due to differences in the price indexes used to deflate the nominal wage series. Clark argues that the main difference between his series and the series of Phelps Brown and Hopkins is due to two things. First, Clark assumes that expenditure weights are fixed, while Phelps Brown and Hopkins use a Laspeyres index that assumes fixed quantity weights. It is well-known that Laspeyres indexes overstate inflation because they do not take account of substitution away from products that become relatively more expensive (see Chapter XX [Measurement Chapter]). Second, Phelps Brown and Hopkins' series for drinks increases 17-fold between 1451-75 and the 1860s, while Clark's series for drinks rises only by 7.4 times. Clark argues that his series is preferable because he has better data on beer, introduces tea earlier, and uses expenditure weights as opposed to quantity weights.

Allen (2007) critiques Clarks real wage series for the period 1770 to 1860 (the sample period studied in Feinstein (1998)) and argues that Feinstein's more pessimistic assessment of the wage gains of laborers during this period is largely correct. Allen argues that the weight Clark assigns to carbohydrates is far too low with most of the discrepancy arising in bread and wheat (which Clark assigns 18.5% weight to while Allen argues for 28.5%). In particular, Allen points to one of Clark's sources for these weights as being unreliable (Vanderlint). Allen also argues that Clark's price series for several products are flawed (while others are improvements on earlier work). He argues that Clark's use of gas prices is inappropriate since gas was mainly used for street lighting before 1850. He argues that Clark's beer series fails to account for a large reduction in the excise tax on beer in 1830. Most importantly, Allen argues that Clark's use of wheat prices as a proxy for bread between 1760 and 1816 is flawed. Clark uses wheat to proxy for bread because he is worried that regulations on the price of bread in this time period may have lead to deterioration in the quality of bread. Allen argues that other bread data does not suffer from this concern and gives different results than Clark's wheat proxy.

Allen presents a new real wage series for the period 1770-1869 that largely synthesizes what he thinks of as the best elements of Feinstein's work and Clark's work (but also makes a few improvements of his own). Allen's series shows an increase in real wages between 1780 and 1850 of 41% (which is close to Feinstein's estimate), while Clark's series shows an increase of 62%. Allen argues that his results are "pessimistic" regarding the gains of labor during this period since the increase in real wages is substantially smaller than the increase in output per worker over this same period (which he reports to be 62% without citing a source). Broadberry et al. (2015) estimate the increase in GDP per person in England over this period to be 42%.

[3]Buringh and van Zanden (2009) estimate the number of manuscripts transcribed in Europe from the 6th to the 15th century and the number of books printed from 1454 to 1800. Their estimates rely on many strong assumptions, especially regarding the number of manuscripts transcribed. But with that caveat in mind, their work indicates that roughly 11 million manuscripts were transcribed in Europe between 500 and 1500, while roughly 12 and a half million books were printed between 1454 and 1500. They, furthermore, estimate that 79 million books were printed between 1501 and 1550. These numbers then grow to roughly 630 million books in the second half of the 18th century.

[4]The death toll estimate for the French Religious Wars is from Knecht (1996), while the population estimate is from Dupaquier (1988). The death rate estimate for the Thirty Years War is from Clodfelter (2002). See Voigtländer and Voth (2013a,c) for a general discussion.

[5]In the Malthus model, steady growth in productivity leads, in the long run, to a constant real wage at a level that is above subsistence. Ignoring plagues for simplicity, population dynamics in the Malthus model are given by $N_{t+1}/N_t = w_t/w_s$ (equation (5)). We show later in this section that a steady growth rate in productivity g_A implies a steady growth rate in the population of $g_N = a^{-1}g_A$. This implies that real wages will stabilize at $w_t = \exp(a^{-1}g_A)w_s > w_s$ in the long run.

[6]Several hypotheses for the fall in fertility between 1880 and 1930 that have been prominent in the literature seem unsatisfactory upon further scrutiny. One such explanation is the notion that women's opportunity cost of raising children rose because their labor market opportunities improved. The labor force participation of women actually fell from 41% to 36% between 1871 and 1911. Another explanation is the shift away from agriculture. Some have argued that having many children was more advantageous to farmers than to urban factory workers because children were more productive on farms. However, even in 1841, 61% of the English population lived in cities. Furthermore, fertility was not lower in cities than in rural areas during this time period. Another potential explanation is a fall in infant mortality. Couples may have had an extra precautionary demand for children due to the high rate of infant mortality before the demographic transition occurred. One reason why this is an unlikely explanation is that infant mortality did not fall until around 1900, twenty years after the rapid drop in fertility rates began. Another reason is that couples could in most cases react to the death of a child by having another child.

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