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, real wages in 1750 were not very different from their level 500 years earlier.

The data series in Figure 1 was constructed by the economic historian Gregory Clark (building on earlier work by many scholars). Constructing such a series for a 750 year period is a monumental task. 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. Clark’s wage and price data come from the accounts of manors, monasteries, churches, colleges, charitable foundations, towns, guilds, and private households from all over England.

Many complications arise when constructing this data series. It is worth thinking carefully about how this is done. For wages, the main complication is 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 and increase in the and index may be simply due to a larger fraction
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.

of quotes coming from high wage areas). For prices, 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 him having data on different goods 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
Many economic historians take issue with the notion that there was no growth in per capita income in England before 1800, arguing instead that per capita growth was small but positive.\(^3\) Here it is important to keep several things in mind. First, it is hard to precisely estimate the long-run growth rate of a series that undergoes large and very persistent swings like the series in Figure 1 before 1800. 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. It may be that per capita output grew but that the lion’s share of the increased income went to wealthier segments of the population. For example, increased Atlantic trade after 1500 (caused in part by the discoveries of Christopher Columbus and Vasco de Gama) lead to a large increase in the size of the relatively wealthy English merchant class. An indirect piece of evidence for this is the explosive growth in the size of London’s population between 1500 to 1700 from 55,000 to 575,000 (Wrigley, 2010, Table 3.2). This development likely increased per capita income in England, but seem not to have benefited laborers.

Third, it may be that income per capita rose because people worked longer hours or more days per year, while wages remained stagnant. In fact, there is some evidence that average days worked in England rose in the 17th and 18th centuries (Broadberry et al., 2015, Table 6.02). This increased industriousness of English workers was part of a broader phenomenon in Western Europe that economic historians have dubbed the \textit{Industrious Revolution} (de Vries, 2008).

Consistent with both the increased wealth from the Atlantic trade and the increased industriousness of English workers, Broadberry et al. (2015) have recently estimated that GDP per person roughly doubled in Britain between 1650 and 1800. In contrast, these authors estimate that real GDP per person in England did not change much between 1270 and 1650 except for a sharp, permanent 30\% increase at the time of the Black Death in 1348.

Finally, Clark’s calculations (as well as Broadberry et al.’s) are heavily dependent on the price index he constructs. As we will discuss in much more detail in chapter XX, 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 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.

However, even granting all these issues, 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 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 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. This dismal logic is evident in the writings of many enlightenment thinkers around 1800 such as Adam Smith and David Ricardo. Today, it is primarily associated with the English scholar Thomas Malthus, who published an essay on
this topic in 1798 titled *An Essay on the Principle of Population* (Malthus, 1798/1993). It is from this essay that economics gets its nickname “The Dismal Science.”

Another potentially very 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 the 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 happened to also be the country with the world’s most advanced political institutions at the time. Perhaps this is not a coincidence.

A third powerful force that can impede growth is vested interests favoring the status quo. Much advancement involves change. In many cases, change threatens the interests of those that are most powerful since those that have attained relative wealth and power within the old system 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. 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.

The invention of the movable type printing press around 1453 by Johannes Gutenberg in modern-day Germany was arguably a watershed moment that greatly changed the balance of power between those seeking to spread ideas and those seeking to suppress them. In the 50 years following the invention of the Gutenberg’s printing press, more books were produced than in the preceeding thousand years (Mokyr, 1990, p. 49). The Reformation, then the Enlightenment, and then the Industrial Revolution (along with political revolutions in England, 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.

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

\[ Y_t = A_t D^{a} L_t^{1-a}, \]

(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, 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

\[ w_t = (1 - a) A_t \left( \frac{D}{L_t} \right)^a, \]

(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 $H_t$):

$$L_t = H_t N_t.$$ (3)

If we assume for simplicity that hours per worker remain constant, i.e., $H_t = H$, then labor supply is driven by changes in the population.

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 birth control, prostitution, and delayed marriage.

In the simplest formulation of Malthus’ model—which we will adopt—abject poverty is the only check that is sufficiently strong to stop the population from growing. The other checks Malthus discusses may help slow population growth, but they are not strong enough to make population growth cease. One way to think about this version of the model is that married couples cannot control their fertility and therefore end up having as many children as they are able to feed and care for given their income. If people behave in this way, the population will grow whenever families on average have enough income to feed and care for more than two offsprings. The following dynamic equation captures this idea:

$$N_{t+1} = \frac{w_t}{w_s} N_t.$$ (4)

We can rewrite this equation as

$$\frac{N_{t+1}}{N_t} = \frac{w_t}{w_s}$$

by dividing through by $N_t$. 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 families are able to feed and care for two offsprings. 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 $N_{t+1}/N_t = w^s/w^s = 1$ which implies that $N_{t+1} = N_t$.

Whenever the wage is above the subsistence level, i.e., $w_t > w^s$, equation (4) implies that $N_{t+1}/N_t = w_t/w^s > 1$ which implies that $N_{t+1} > N_t$. In other words, whenever the wage is above subsistence the population is growing, as Malthus theorized. 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 year.

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 (4) for population growth:

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

(5)

Here $\xi_t$ denotes the plague shock at time $t$. 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.

### 2.1 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:

$$w_t = (1 - a)A_t \left( \frac{D}{HN_t} \right)^a.$$  \hspace{1cm} (6)

Equations (5)—the population growth equation—and equation (6)—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 (5) and (6) 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 (6) to plug in for $w_t$ in equation (5) yields

$$N_{t+1} = \phi A_t \xi_t N_t^{1-a},$$  \hspace{1cm} (7)

where I have defined a new constant $\phi = (1 - a)D^a/(w^a H^a)$ to reduce the messiness of this equation. Notice that given an initial population $N_0$ and values for the exogenous variables $A_t$ and $\xi_t$ at all points in time, one can use equation (7) 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 (7) 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 (7) 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 $\xi_t$ are exogenous, they should be considered given. The model does not provide a theory for the exogenous variables $A_t$ and $\xi_t$. 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.

### 2.2 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 2. Here I plot the simplified population growth equation (equation (7)) 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 (7)).

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 2. 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 $N_{t+1} = N_t$ 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 3. 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 3. 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 3. 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 3 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
Figure 3: Population Convergence in the Malthus Model

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 population 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 (7). 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

$$\bar{N} = \phi^{1/a}. \quad (8)$$

What about real wages? Figure 4 plots the labor demand curve in the Malthus model (equation (6)) 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 4 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 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 4—real wages rise. The population will stop shrinking exactly when wages reach subsistence (since that is the point at which family’s 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.

It is clear from this discussion that the downward slope of the labor demand curve in Figure 4 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 return 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.

2.3 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 standard 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 3.
Let’s consider what the Malthus model implies about the evolution of the population and real wages (living standards) after a plague strikes. Figure 5 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 $\xi_0 < 1$. This shifts the population growth line from its normal level (the solid population growth line in Figure 5) down to a lower level (the broken population growth line in Figure 5) for that single period. The population in period 1 (the period after the plague strikes) is then the value of this temporary population growth line at $\bar{N}$ (point A in Figure 5). This is substantially lower than $\bar{N}$ (the value of the normal population growth line at $\bar{N}$) reflecting the fact that the plague kills off a portion of the population.

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 5). 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 5) 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 2.2 (see Figure 3). 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 5) helps us understand the consequences of the plague for real wages. The plague does not shift the labor demand curve (see equation (6)). 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 $w^*$. 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 6 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 $w^*$. 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.
2.4 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 where 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. In contrast, 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 technological improvements such as those mentioned above 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 7 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 $w^*$. This point is labeled $A$ in both panels of figure 7. 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 (7) and (6), 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 7 to point B, when the level 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 $N$ to $N_{new}$ in response to the increase in technology. $N_{new}$ is the new steady state level of the population when the level of technology is $A_0$. 

Figure 7: The Consequences of an Improvement in Technology
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 7). 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 gradually 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 8 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 sometime 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 bathtub 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.
3 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.

3.1 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 9 plots the evolution of real wages and the population in England over the period 1250 to 1640 in two panels 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.

Consider first panel (a) that covers the period 1250 to 1450. This panel 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.

Next consider panel (b) that covers the period 1450 to 1640. 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 4. It plots a negatively sloped labor demand curve. The data in Figure 9 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.
Figure 9: Real Wages and Population in England from 1250 to 1640

Note: 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.
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.

3.2 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.

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.

3.3 Technological Growth in England from 1250-1860

There is a second important lesson to be learned from the data in Figure 9. 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 9 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 can’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 9 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 argu-
ment 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 along.

Consider next Figure 10. This figure extends the data plotted in Figure 9 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 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.

The large increase in technological growth—i.e., the speed with which the points
in Figure 10 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 10 right after 1800. Something dramatic and revolutionary did seem to occur in Britain around 1800. Referring to this as the Industrial Revolution seem fitting.

4 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 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 explains all of human history except for the last 200 years. As we have seen in this chapter, Malthus’ model is spectacularly successful at 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. As we see in Figure 11, 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? The first thing that changed was the pace of productivity growth. This is evident from Figure 10. Productivity growth jumped

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**Figure 11: 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.*
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. The reason is that the population pressures emphasized in Malthus’ theory—i.e., the notion that higher real wages result in population growth which put pressure on real wages to fall—are a weak force. It takes a long time for the population to rise. It may be that the level of population growth after 1800 was simply high enough to overwhelm the population force that tended to drag down real wages.

Figure 10 makes clear that the increases in real wages that occurred from 1800 to 1860 coincided with quite substantial increases in the population. In that sense, Malthus’ model was still accurate: higher real wages seemed to be leading to increases in the population. But these increases in the population were evidently not large enough to push real wages down to subsistence. Perhaps productivity growth was simply so high that population growth was not able to keep up.
Malthus’ theory of the relationship between real wages and the population did, however, eventually break down. Starting in the second half of the 19th century, fertility rates fell by large amounts. This change is called the *demographic transition*. Today the relationship between real wages and fertility in the world’s most economically developed countries is negative as opposed to positive and population growth in these countries is small. The causes of the demographic transition are still debated. [XXX Expand on demographic transition and add citations XXX]
Notes


2One 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 of 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). 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 Clark’s 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 the 1770’s and the 1860’s of roughly 40% (which is close to Feinstein’s estimate), while Clark’s series shows an increase of roughly 75%. 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 80%.

3For example, Mokyr (2009, p. 4) writes “few scholars would disagree that by the Glorious Revolution in 1688 ... material life and economic institutions had changed a great deal since the Norman conquest, and that consumption patterns and aggregate output had grown in the long haul.” but then adds “And yet by modern standards change had been extremely slow.”

4The 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.
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