The Industrial Revolution and the Demographic Transition

BY AUBHIK KHAN

In the 19th century, the United Kingdom began a period of economic transformation known as the Industrial Revolution. It's commonly believed that this era opened as new inventions improved the technologies used to produce goods and provide services. However, we now know that such improvements affected only a relatively small part of the economy. Nonetheless, output rose during the first stage of the Industrial Revolution because of capital accumulation. One explanation for this increase in capital may be that another revolution occurred in Britain around the same time: the demographic transition. In this article, Aubhik Khan outlines some evidence on the Industrial Revolution and the demographic transition, then presents two economic theories that link the two phenomena.

In the 19th century, the United Kingdom began a period of economic transformation known as the Industrial Revolution. While the typical reader may think of Dickensian mills when hearing of the Industrial Revolution and of the end of a pastoral society, for most economists, the Industrial Revolution is associated with a change in the long-run or average rate of growth of per capita income. Also, in the 19th century, a steady rise in living standards began that has, in some sense, never ceased. As a result, people are now accustomed to economic growth. They expect it alongside the sometimes gradual, sometimes abrupt changes to the organization of industry and society associated with technological change.

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Prior to the Industrial Revolution, the notion that there would be an improvement in people's standards of living almost every year would be unfamiliar not only to laypersons, whether common people or the nobility, but also to economists working in that period.

It is commonly believed that the Industrial Revolution began as new inventions improved the technologies used to produce goods and provide services. However, there is a difficulty with this account: We now know that such improvements affected only a few sectors that represented a small part of the economy. In the absence of widespread improvements in technology, output rose during the first stage of the Industrial Revolution because of capital accumulation — that is, because there was an increase in the quantity of machines and tools available to each worker.

Why did society suddenly choose to increase capital at an increasing rate? One answer may be that another revolution occurred in Britain around the same time: the demographic transition. This demographic transition saw the rate of population growth in the United Kingdom first rise, and then later fall. During this period, adult mortality fell, then child and infant mortality, then finally fertility.

After presenting some evidence on the Industrial Revolution and the demographic transition, I present two economic theories that link the two phenomena. The first explains the slowdown in population growth as a result of technological progress. It represents the conventional view that the Industrial Revolution drove the demographic transition. An influential summary of this theory is contained in

the 2002 book written by Nobel laureate Robert E. Lucas. The second economic theory — which is part of my ongoing research with Michele Boldrin and Larry Jones — suggests that causality runs in the opposite direction. These different theories have different implications for how modern developing economies may improve their rate of growth. For example, to the extent that demographic transitions affect economic development, policy that reduces mortality and fertility may raise the level of economic development.

THE INDUSTRIAL REVOLUTION

Real Wages and Population Stagnated Until 1800. Between 1250 and 1800 there was little sustained improvement in the British economy. The economic history of Great Britain over this period is reasonably well captured by a model originally developed by Robert Malthus.

Malthus's theory suggested an inverse relation between the real wage (the wage paid to laborers measured in terms of the goods it can provide) and population. This inverse relation stems from the value of labor. For example, when population was lower than its average level, labor would be relatively scarce. This would drive up real wages as landowners bid for scarce laborers. Increases in real wages would allow laborers to purchase more goods and services, including better food and shelter. Their standard of living would rise. This rise in living standards would also increase the number of children born that would survive into adulthood. This would move population back to its average level and reduce the scarcity of labor. As a consequence, landowners, no longer having difficulty operating their farms, would reduce the real wage back to its average level. The resultant decline in the living standards of workers would end the growth in population.

Malthus's theory could explain the persistent rise in the real wage in England during the 15th and 16th centuries. Over this time the Black Death sharply reduced the number of laborers.[1] However, the theory also implied that society would always remain poor and that the "perfectibility" of society was infeasible. Whenever living conditions temporarily improved, population growth would bring them back down. This somewhat bleak outlook on life was consistent with the observation that the real wage was about the same in 1740 as it had been 350 years before.

Malthus's theory suggested an inverse relation between the real wage (the wage paid to laborers measured in terms of the goods it can provide) and population.

Figure 1 is taken from the influential paper by Gary Hansen and Edward Prescott. It shows the population of England and the average real wage paid on farms from the end of the 13th to the middle of the 19th century. Over this period farm laborers had little to no assets, and they worked as many hours as their employers demanded, subject to their health. As a result, their real wage can be taken as a very good indicator of their real income.

What is striking from the figure, when viewed through the eyes of someone who lives in the 21st century, is how little net change in living conditions there was over the 500-year period. As stated above, the level of the real wage in 1390 is very close to that observed in 1740. Equally striking to someone living today is that there is little discernible difference in the population of England between 1350 and 1740. For comparison, the population of the United States was 248 million in 1990, having almost doubled in the 50 years since 1940, when it was 132 million.[2]

The small overall changes in real wages and population provide support for Malthus's theory of a natural long-run level of population associated with a particular real wage. Furthermore, the rise in real wages in the 15th and 16th centuries, which occurred at the same time that periodic outbreaks of plague led to an extraordinary rise in mortality and reduction in population, is also consistent with the Malthusian view.

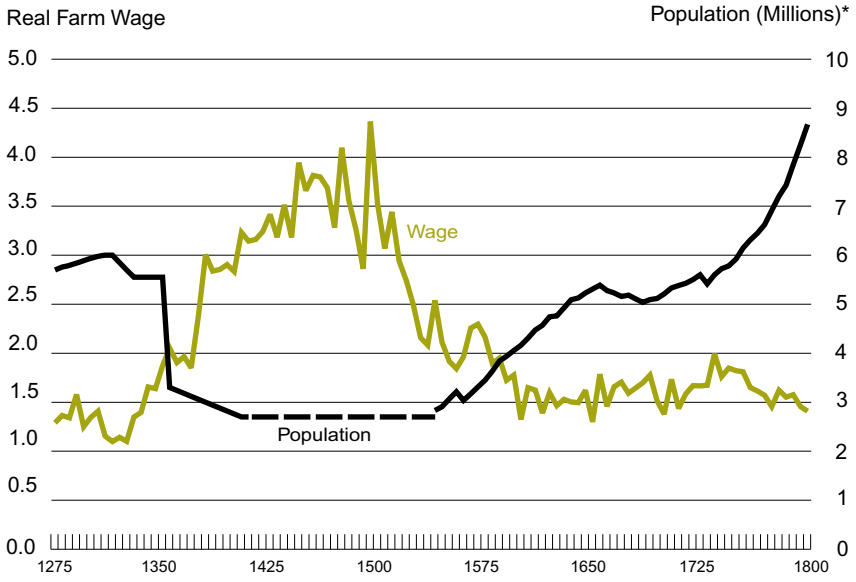
After 1800 Both Real Wages and Population Grew. This inverse relationship between real wages and population began to change around the beginning of the 19th century. Between 1780 and 1989, the real wage rose 22-fold. The English Industrial Revolution had arrived, bringing with it a sustained improvement in living conditions.

[1] Catastrophic outbreaks of plague afflicted the English periodically between the mid-14th century and the 17th century. One of these outbreaks, known as the Great Plague (1665-1666), is estimated to have cost between 75,000 and 100,000 lives in London, about one-fifth of the city's population.

[2] The population data, which include immigration, are taken from the U.S. census and are available at http://www.census.gov/population/censusdata/table-2.pdf.

FIGURE 1

The English Economy: Population and Real Farm Wage



* Dashed line indicates missing data.
Source: Figure 1 in Hansen and Prescott (2002)

As we know, before the Industrial Revolution, there was little change in living standards. If we set the real GDP per person in Great Britain to 100 in 1566, it had risen to only 130 by 1806. This implies an annual rate of economic growth in income per person of 0.11 percent over a 240-year period. In other words, there was no discernible improvement, at least on average, in the quality of life for most people.

However, beginning in the early 19th century, growth rates began to rise. Between 1806 and 1906, income per person grew at an average of 0.9 percent a year, that is, more than eight times faster. From 1906 to 1990, income per person in the United Kingdom has grown at an annual rate of 1.5 percent a year. This is more than 13 times faster than the average growth rate between 1566 and 1806.

Problems with the Technological Explanation. In the traditional view, new inventions brought about this new era of persistent growth. Examples include James Watt's improved steam engine, John Kay's fly shuttle, and James Hargreaves' spinning jenny. However, as famously argued by N.F.R. Crafts and C. Knick Harley, while these and several other well-known discoveries were applied to production in the 19th century, their impact was limited to just a few sectors in the economy in the early part of the Industrial Revolution.

Gregory Clark's quantitative assessment of the role of technological progress in the 18th century supports Crafts and Harley's view. To assess the impact of technological progress on the economy, we must break overall production per person into components that are attributable to capital, labor, and total factor productivity. This is the famous growth decomposition first used by Nobel laureate Robert Solow in his 1957 paper. Solow assumes that the output of goods and services requires two inputs. The first is labor. The total quantity of labor used by a business is measured as the number of workers times the average hours worked by each. A rise in the quantity of labor, either because there are more workers or because they work longer hours, increases the total quantity of goods or services produced by the business. The second input is capital, the quantity of machines and buildings used to produce goods and services. An increase in capital means that more machines and buildings are used for a given method of production. The third component is a change in the method of production — that is, in the overall level of technology — and is called a change in total factor productivity. Inventions that allow more output to be produced without increasing the quantity of inputs lead to a rise in total factor productivity.

Gregory Clark extends the Solow method to include land as a factor of production. Separating out changes in output per worker between 1700 and 1861, he finds that total factor productivity growth shows little rise until the middle of the 19th century. This means that the role of discovery and innovation — that is, technological progress — in spurring the Industrial Revolution was relatively minor. Instead, for some reason, society as a whole began to invest more heavily in capital, that is, in machines. Since capital is accumulated by using current production to increase machines and buildings instead of consuming it, an increase in capital implies a rise in the savings rate.[3] I will discuss a possible reason for this change in the rate at which society saved output below.

[3] This is strictly true only for a country that can't borrow from abroad to finance investment. While there was international borrowing and lending in 18th century England, access to such funds was limited.

THE DEMOGRAPHIC TRANSITION

Over the same two centuries associated with the English Industrial Revolution, there were dramatic changes in population growth and life expectancy driven by changes in the underlying factors that explain them: fertility and mortality. Population growth rose in England around 1700 and continued to rise until reaching a peak of 1.36 percent a year during the period 1791 to 1831. Looking across centuries, we find that between 1680 and 1820 the population of England increased 133 percent. Next, between 1820 and 1900 it rose another 166 percent. When compared with other large European nations, this represents a dramatic increase in population. For example, the corresponding increases in France were 29 percent and 26 percent (Figure 2).

Two economic historians, E.A. Wrigley and Robert Schofield, describe a famous finding in their 1981 book: Most of the increase in population was the result of a rise in fertility. We see little change in life expectancy between 1700 and 1870 largely because infant and child mortality did not fall until late in the 18th century. For example, the expected life span was 36.8 years between 1701 and 1711; 160 years later, between 1861 and 1871, it had risen to only 40.7 years. Notably, the mortality rates of people between the ages of five and 20 fell markedly over this period. For the years between 1735 and 1970, Figure 3 plots the fraction of children that survived to their fifth and 20th year of life.

Aside from the fall in child mortality, a dramatic rise in fertility occurred during this period. Over the 250 years before 1800, the crude birth rate (a measure of fertility) first fell, then rose. However, in 1796, at 35.51 births per 1000 people, it was no different from its level in 1551. Thereafter, there is a notable increase in fertility until it peaks in 1821 at 40.22 births per 1000. Fertility remained high until the beginning of the 20th century when it began to decline, as mortality had done earlier.

These changes in fertility, mortality, and population growth are known as a demographic transition (Figure 4). A demographic transition involves four stages, broad patterns that social scientists have observed across countries. In the first stage, both fertility and mortality are high, and population growth is low. In the second stage, mortality begins to fall first, without a change in fertility. Population growth rises over this second stage. Over the third stage, fertility falls. In the fourth stage, both mortality and fertility settle at low levels, and population growth is once again low (although the level of population has now risen). The transition in England is exceptional in that the high initial level of fertility, rather than simply falling sometime after the second stage, first rose only to fall much later on.

THE LINK BETWEEN FERTILITY AND ECONOMIC GROWTH: TWO ECONOMIC THEORIES

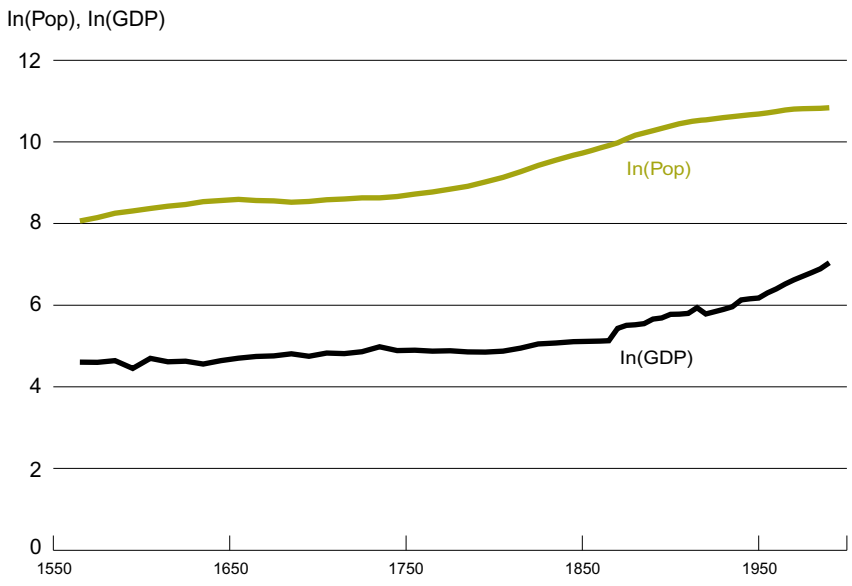
Economists and other social scientists have produced a huge literature about the Industrial Revolution. There is also a large body of work that studies the demographic transition. Here I discuss only economic theories that link the two events, and even then I discuss only one example of each of the two theories.

The first theory is by far the most commonly accepted, and I will call it the technology-led theory. This theory suggests that improvements in technology led to the Industrial Revolution and that the associated rise in the standard of living reduced mortality. Fertility fell as people began to invest in the quality of their children.

The second theory is relatively new and undeveloped and, therefore, is

FIGURE 2

UK Population and GDP Per Capita, 1565 to 1990



Source: Boldrin, Jones, and Khan (2005)

far less widely accepted. It argues that the demographic transition preceded economic development and, moreover, was responsible for some of the improvement in living standards. I will call it the demography-led theory.

Economic Models of Fertility. Both theories rely on an economic model of household fertility choice, a theory of how parents decide how many children to have. When studying fertility choices of households, economists assume that parents care about their children's happiness or welfare, as well as their own. With this assumption, economists have gained powerful insights about fertility choices by a household that wishes to maximize its welfare. The most famous proponents of this view are Robert Barro and Gary Becker, and I will describe a very simple version of the approach taken in their 1989 paper.

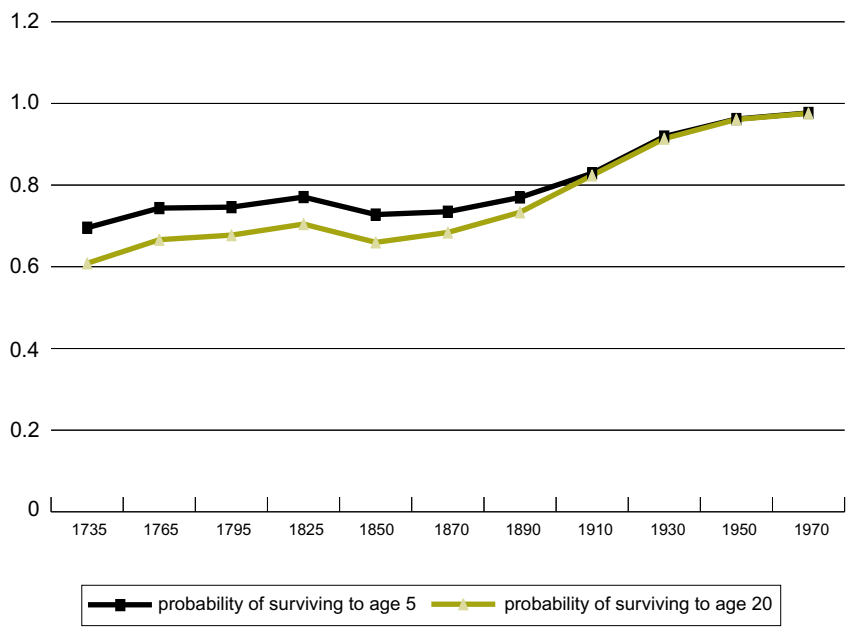
Barro and Becker developed a model in which parents care about both the number of children they have and the welfare of those children. At the same time, parents also value their own direct consumption of goods and services. Given their income and their time, they must trade off their own welfare from consuming goods against their welfare from having children, as well as their children's welfare.[4]

In applications of the Barro and Becker model to economic development, parents are able to affect the welfare of their children by investing in their education. Specifically, parents

[4] An alternative view of population growth is discussed by Stephen Parente and Edward Prescott in their chapter in the *Handbook of Economic Growth*. They argue that fertility choices are not made at the household level but at the societal level and that they are implemented through a range of policies that either promote or hinder families' choices about how many children to have. Parente and Prescott suggest that these policies arose because pre-industrial societies had to defend land.

FIGURE 3

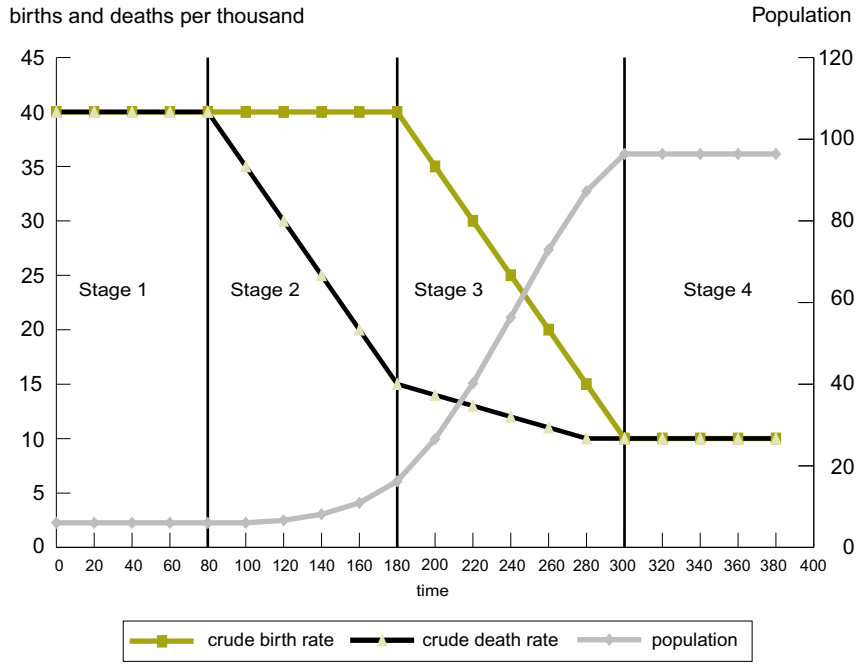
English Survival Rates



Source: Boldrin, Jones, and Khan (2005)

FIGURE 4

A Stylized Demographic Transition



choose how much costly human capital to give to each child.[5] Higher levels of human capital, by increasing children's skills, allow them to earn more real income. This, in turn, enables them to raise their own consumption and thus their welfare. Thus, parents face two choices involving their children: They must decide how many children to bear, and they must determine the human capital investment in each child.

Technology Leads Demography. The technology-led theory finds that improvements in technology increase the return to investment in human capital. Prominent examples of this theory are contained in the works of Gary Becker, Kevin Murphy, and Robert Tamura, and in the work of Lucas. Before the technological improvements that led to the Industrial Revolution were implemented, the return to investing in the human capital of each child was relatively low, at least given the costs, because the difference in the earnings of skilled and unskilled workers was small. However, the introduction of new technologies brought with it more complex methods of production, and total factor productivity increased. In such environments skilled workers became more valuable than they had previously been, and the wage premium paid to skilled workers rose.

The rise in the skill premium led those parents who could afford it to invest more heavily in the human capital of their children. Over time, improvements in income led to more and more parents being able to afford to educate their children. Both the rise in total factor productivity and the increase in human capital led to increases in the real earnings of workers. Living standards improved. Moreover, the move to increased investment in human capital increased the cost of having children for parents. As a result, the number of children per family fell over time.

Before the technological improvements that led to the Industrial Revolution were implemented, the return to investing in the human capital of each child was relatively low.

It is convenient shorthand to describe children with a higher level of human capital as children with a higher skill quality.[6] According to economic theories of fertility, there is a tradeoff between the quality and the quantity of children a family has. The technology-led theory argues that new inventions moved families to increase quality at the expense of quantity and that this reduced fertility.

This conventional view can explain the fall in fertility that occurred at the end of the Industrial Revolution. However, a weakness is that it relies, to some extent, on the thesis that the Industrial Revolution was spurred by technological improvements. As I discussed above, there is some evidence to suggest that this was not initially true. It also suffers from another problem: Economic growth rose long before fertility fell.

Demography Leads Technology. The demography-led theory centers on the effects of the fall in mortality, for children age five and above, that began in the 18th century. Investing in a child's human capital will turn out to be a waste if he or she does not survive long enough to benefit from it. Thus, investment in human capital is very risky when childhood mortality is high. However, if children of school age are likely to live on to adulthood, costly expenditures on their schooling become less risky.

The demography-led theory suggests that reductions in mortality for children age five and older increased the return to human capital investments for children, since, once they are old enough to receive formal education and specialized training in skills, they would also be more likely to live on to earn the higher wages of skilled workers. As before, this drives an increase in parents' investments in children and a reduction in fertility.

As more skilled workers are able to make better use of machines, increases in human capital raise the returns to investing in physical capital. At the same time, the higher earnings by households with skilled workers raise average household income. This allows for a rise in savings, which, in turn, funds physical capital investment in the economy. Driven by the rise in human capital and the resultant increase in income, the stock of physical capital grows. This availability of better equipment for skilled workers compounds the effects of the initial rise in human capital, and there is further accumulation of both human and physical capital.

[5] Economists use the term human capital to describe a worker's skills and ability. Investment in human capital is usually believed to be time-intensive and includes years spent in formal education as well as on-the-job training.

[6] Obviously, a person's quality can't be reduced to his or her skill level. Using the terminology of a quality/quantity tradeoff, however, places the family's problem in a familiar economic framework that allows for clarity of exposition.

The demography-led theory's appeal is that it doesn't rely on total factor productivity growth to explain the fall in fertility. However, it does not explain the reductions in mortality that occurred during the Industrial Revolution. These are explained implicitly by the technology-driven theory as the natural consequence of improvements in medical technology. Explaining them explicitly is more important for the demography-driven theory, since it relies heavily on changes in mortality. Another difficulty with the demography-led theory is that it is, as of yet, insufficiently developed to evaluate it against data.

Both the technology-led theory and the demography-led theory explain changes in growth and fertility through parents' decisions on how many children to have and how much to invest in their education, skills, and general well-being. Both emphasize the quality/quantity tradeoff. What distinguishes the two theories is why this tradeoff changes. In the technology-led theory, improvements in technology raise the return to investment in the human capital of children. In the demography-led theory, this return rises because older children, who are the recipients of such investments, live longer. This increases the benefit they may expect from human capital investment.

CONCLUSION

In the 17th and 18th centuries, Great Britain experienced an economic transformation, the Industrial Revolution, which began a period of economic growth and prosperity that defines the modern era. Standards of living that had fluctuated for hundreds of years now began to improve steadily.

Roughly over the same period, a demographic transition occurred. First, adult mortality fell; sometime later there was a decline in child and infant mortality. Fertility initially rose and then fell alongside mortality. These changes led to a sharp rise in population growth rates, which subsided only after many decades.

Economic theory offers explanations that uncover the links between the Industrial Revolution and the demographic transformation. I have discussed two theories. The first, the technology-led theory, is widely understood and supported. The second, the demography-led theory, is relatively new. It has been developed partly in response to several difficulties with the technology-led theory. Most notably, the timing of events suggests some difficulty, though perhaps not an insurmountable one, in explaining the proposition that an increase in income led to a fall in fertility. The Industrial Revolution began at the end of the 18th century, but fertility did not fall until 100 years later. This timing is consistent with the demography-led theory, but a full evaluation of the relative merits of the two theories will require a more careful empirical examination. ER

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