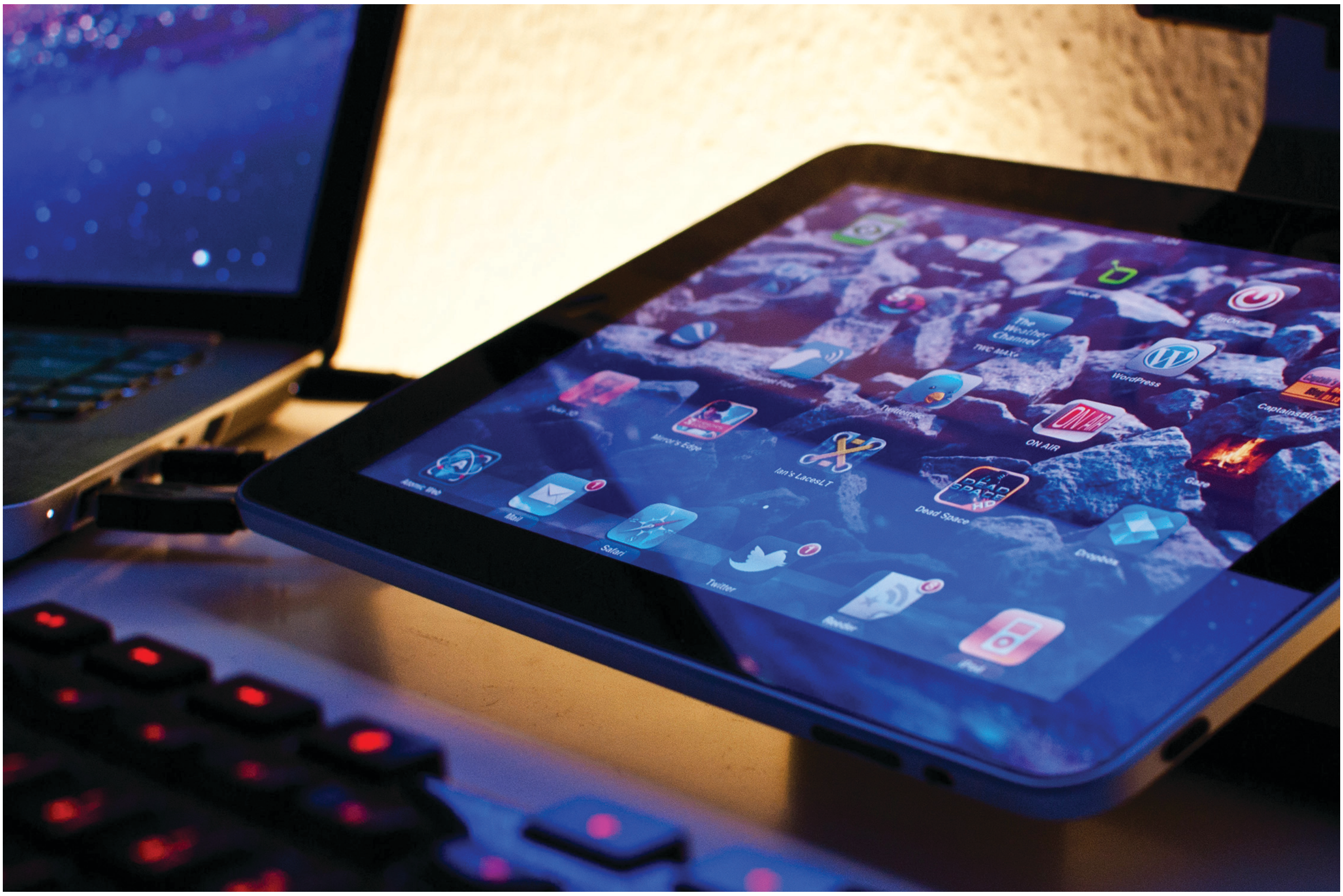
Information technology: a new era?



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Introduction

This course takes one aspect of the debate concerning the new economy – innovation in the form of the introduction of information and communication technologies – and places it in the historical context of industrial revolutions. Is the new economy really new or 'just another' industrial revolution?

This OpenLearn course provides a sample of Level 1 study in Sociology.

Learning Outcomes

After studying this course, you should be able to:

- understand the relationship between technological change and industrial revolutions
- appreciate the pervasive effect that new technologies can have on the economy and, in particular, on productivity
- understand how industry dynamics can be analysed using the ‘industrial life cycle’ model
- use data and historical examples to support economic arguments.

1 Technological advancement

> Everything that can be invented has been invented.
>
> (The Commissioner of the United States Office of Patents, 1899, recommending that his office be abolished, quoted in The Economist, 2000, p. 5)

> There is nothing now to be foreseen which can prevent the United States from enjoying an era of business prosperity which is entirely without equal in the pages of trade history.
>
> (Sutliff, 1901)

The rise of information and communication technologies (ICT) – that is, computers, software, telecommunications and the internet – and the large impact that these new technologies are having on the way that society functions, have prompted many to claim that we have entered a new era, often referred to as the 'Third Industrial Revolution', the 'information age' or the 'new economy'. Previous industrial revolutions were also linked to the rise of new technologies: the First Industrial Revolution, concentrated in Britain from around 1760 to 1850, introduced Cort's puddling and rolling process for making iron, Crompton's mule for spinning cotton and the Watt steam engine; the Second Industrial Revolution, from around 1890 to 1930, witnessed the development of electricity, the internal-combustion engine, the railway and the chemical industry. In each of these cases, the new technologies allowed new industries to develop and economic growth to increase.

The concept of the 'new economy' is thus a claim that the emergence of new information technology (IT) was responsible for the economic prosperity (e.g. rising incomes, rising employment) experienced by most Western countries in the 1990s. This was the decade in which personal computers (PCs) were diffused throughout the economy, and the decade which saw the commercial rise of the World Wide Web. The PC reached a 50 per cent household penetration rate in the USA only in 1999, while before 1990 the internet was used mainly by the US Defense Department, not for commercial purposes.

However, as the two introductory quotations indicate, proclamations that we have entered a 'new' era are not new. In fact, the advent of electricity, the internal-combustion engine and the radio telegraph witnessed similar proclamations about the future. They too emerged during periods of prosperity; for example, electricity and the automobile diffused through the economy during the prosperous and 'Roaring' 1920s. So how can we tell whether we are really entering a qualitatively new era or whether recent changes have simply been a quantitative extension of the past?

This course uses tools and frameworks from economics to study this question. It focuses on the historical and theoretical relationship between changes in technology, productivity and economic growth. The key driving force discussed will be *technological change*: that is, organisational and technical changes in the way that societies organise production and distribution. The question is: what exactly is so *new* about the 'new economy'? Some economists focus was on the effect of new technologies and work practices on the way that people live and work, here the focus is on the organisation and evolution of firms and industries.

In each industrial revolution (including the current one), important *non-technological* factors have influenced industry dynamics and growth. Socio-political factors have been particularly prominent. For example, the rise of industrial trade unions in the Second Industrial Revolution greatly affected firm-level, industry-level and country-level growth. In this course, however, the analysis is limited to the role of technology.

We shall conduct our investigation by focusing on two related questions, neither of which has a clear-cut answer. The goal of the course is to help you to think about these questions using concepts and tools from economics.

First, after a brief overview of the concept of the industrial revolution, I shall ask whether the rise of IT has significantly affected economic growth, as new technologies did in previous eras. Focusing on the effect of technology on economy-wide growth implies that the perspective is a macroeconomic one. Macroeconomics looks at the functioning of the economy as a whole.

Second, I shall take a more microeconomic perspective. Microeconomics looks at the functioning of individual elements of the economy, whether they be consumers, firms, industries or markets. I shall ask whether the rise of new information technologies has fundamentally changed the way that individual firms and industries operate. To do this, I shall compare the patterns that characterised the early phase of a traditional industry with those that characterised the early phase of a relatively new industry. The traditional industry (one that is today considered to be relatively 'mature', not high growth) is the US automobile industry from 1900 to 1930, while the relatively new industry is the personal computer industry from 1975 to 2000. The similarities will lead us to ask whether we are really in a 'new economy' or simply in an economy driven, as in some past eras, by the development of new industries.

2 Technological change and economic growth

2.1 Industrial revolutions and technological change

In this section I shall look at the way that technological innovations in previous eras, such as the invention of electricity in the early 1900s, radically affected the way society organised production and at how these changes spurred general economic growth. In many instances, the changes were so large that they defined an entire period, just as the rise of information technologies has led some to call the current era the ‘information age’.

The way that technological change can fundamentally alter society is best viewed through the lens of previous industrial revolutions. The term **Industrial Revolution** usually refers specifically to the series of technological changes that occurred in England between 1760 and 1850 (such as steam power). More generally, the term refers to eras when rapid and significant technological changes fundamentally alter the way that production is carried out in society, affecting not only how people work but also how they live their lives. Consider the impact that electricity in the Second Industrial Revolution had not only on factories but also on the lives of families in their homes. Thus an industrial revolution occurs when new technological inventions and innovations fundamentally transform the production processes of goods and services to such an extent that all society is affected.

For our purposes the words ‘invention’ and ‘innovation’ can be used interchangeably. More specifically, however, the term ‘invention’ refers to the discovery of new products or processes, while ‘innovation’ refers to the commercialisation (bringing to the market) of new products or processes. Furthermore, we can distinguish between *product* innovations and *process* innovations. Product innovations result in the production of a new product, such as the change from a three-wheel car to a four-wheel car, or the change from LP records to CDs. Process innovations increase the efficiency of the methods of production of existing products, for example the invention of the assembly-line technique.

The inventions and innovations that form industrial revolutions are those that open new doors and create new ways of doing things, not simply those that fill gaps in existing ways of doing things (Mokyr, 1997). The core of the First Industrial Revolution in the eighteenth century was a succession of technological changes that brought about material advances in three basic areas: (1) the substitution of mechanical devices (such as machines) for human labour; (2) the substitution of inanimate sources of power (such as steam) for animate sources of power (such as horse power); and (3) the substitution of mineral raw materials for vegetable or animal substances, and in general the use of new and more abundant raw materials (Landes, 1972).

These changes in technology and equipment occurred simultaneously with changes in *organisational* arrangements. For example, at the end of the nineteenth century the rise of electricity and the internal-combustion engine allowed the factory system to emerge, which radically changed the organisation of work. The factory system, used first for the production of cotton but then extended to other industries, created a new, unified system of production which replaced the craft labour carried out in individual workshops. The main innovation of this new system was that it allowed workers to be brought together for the first time under common supervision with strict discipline, and it also introduced the use of a central, usually inanimate, source of power. The factory system enabled production to become more efficient as it allowed the company to spread its costs over a much larger output, a dynamic called 'economies of scale'.

Economists interested in the pervasive effects of technological change in different industrial revolutions have devised the concept of a **general purpose technology** (GPT). A GPT is a technology that is general enough to be used in various industries and has a strong impact on their functioning. There are four main characteristics of a GPT (Lipsey et al., 1998). As you read the list, consider how a new technology such as electricity or information technology fulfils each criterion.

1. It must have a wide scope for improvement and elaboration. This means that the technology does not appear as a complete and final solution, but as a technology that can be improved through the different opportunities for technological change that surround it.
2. It must be applicable across a broad range of uses. This means that its use is not restricted, for example, to only one industry but open to many different types of industries and consumers.
3. It must have a potential use in a wide variety of products and processes. This means that the new technology should not result in the creation of only one set of products (such as a computer), but a wide set of products (such as complex new air-traffic control systems or new inventory controls).
4. It must have strong complementarities with existing or potential new technologies. This means that the technology does not only replace existing methods but also works with them, ensuring an even broader impact on the systems of production and distribution.

Examples of GPTs include different power delivery systems (water-wheel, steam, electricity, internal-combustion engine), transport innovations (railways and motor vehicles), lasers and the internet. The invention of the internal-combustion engine not only made possible personal automobiles, motor transport and air transport, but also created 'derivative' inventions such as the suburb, the motorway and the supermarket. Electricity allowed the work day to be extended (allowing for different shifts in a 24-hour period), gave a huge impetus to the entertainment industry, and greatly enhanced manufacturing process technologies. (We shall also see how it created the conditions for 'mass production' via the moving assembly line.)

GPTs are important because they spur technological change in different areas (and this effect is behind the first three characteristics of GPTs listed above). In fact, radical technological changes are often **cumulative changes**: change in one area leads to change in another area. David Landes is an economic historian and his account of the way in which the invention of the steam engine caused changes in many different industries has become well known. He calls this process 'technological interrelatedness'.

> In all this diversity of technological improvement, the unity of movement is apparent: change begat change. For one thing, many technical improvements were feasible only after advances in associated fields. The steam engine is a classic example of this technological interrelatedness: it was impossible to produce an effective condensing engine until better methods of metal working could turn out accurate cylinders. For another, the gains in productivity and output of a given innovation inevitably exerted pressure on related industrial

> operations. The demand for coal pushed mines deeper until water seepage became a serious hazard; the answer was the creation of a more efficient pump, the atmospheric steam engine. A cheap supply of coal proved a godsend for the iron industry, which was stifling for lack of fuel. In the meantime, the invention and diffusion of machinery in the textile manufacture and other industries created a new demand for energy, hence for coal and steam engines; and these engines, and the machines themselves, had a voracious appetite for iron, which called for further coal and power. Steam also made possible the factory city, which used unheard-of quantities of iron (hence coal) in its many-storied mills and its water and sewage systems. At the same time, the processing of the flow of manufactured commodities required great amounts of chemical substances: alkalis, acids, and dyes, many of them consuming mountains of fuel in the making. And all of these products – iron, textiles, chemicals – depended on large-scale movements of goods on land and on sea, from the sources of the raw materials into the factories and out again to near and distant markets. The opportunity thus created and the possibilities of the new technology combined to produce the railroad and steamship, which of course added to the demand for iron and fuel while expanding the market for factory products. And so on, in ever-widening circles.
>
> (Landes, 1972, pp. 2–3)

Question 1

Can you think of new industries that have grown out of the PC and the internet?

Answer

You may have thought of online shopping, internet banking, digital cameras, information services (such as online recipes) and computer desks. Having reflected on the nature of technological change and its role in defining industrial revolutions, we shall now examine how technological change affects the efficiency of firms and hence general economic growth.

2.2 The effect of technology on productivity

In each industrial revolution, new inventions radically changed the way that production and distribution were organised, and often led to large and rapid increases in the efficiency of production. The rise of electricity, for example, allowed US productivity to increase in the manufacturing sector (as opposed to the agricultural or service sector) by more than 5 per cent per annum throughout the 1920s.

Let us pause a moment and consider what this means. The term **productivity** refers to the amount of output that a given amount of inputs (such as hours of labour) can produce. (Productivity is an indicator of the efficiency of production or distribution. Labour productivity can be measured as output produced per hour of labour.) For example, consider an automobile factory that is able to produce 10 cars per day using 100 hours of labour. If a new invention permits those same workers to produce 20 cars in the same amount of time, their productivity has been doubled.

The productivity of a whole economy, such as the UK economy – as opposed to a particular factory – is measured by first calculating the total output produced by the economy in one year. This is called the GDP or gross domestic product. Total output divided by total labour hours in the year gives us a measure of labour productivity. A 5 per cent growth in UK productivity over a year means that the UK economy has become 5 per cent more productive than it was in the previous year. This should mean that the economy can produce 5 per cent more output (GDP) with the same amount of inputs.

Question 2

Stop here and check your understanding of percentages and growth rates. They are quite simple, but it is important to get them clear. If a group of workers produces 10 000 units of output in one year, and 12 000 units the next year, how would you calculate the percentage increase in productivity?

Answer

You want to know the percentage increase represented by the second year's output, 12 000, over the first year's output, 10 000. Subtracting 10 000 from 12 000 gives us the increase. Divide the answer by 10 000 to calculate the increase relative to the first year. Then multiply by 100 to turn the answer into a percentage (the dot‘ ·’ means ‘multiplied by’).

$$12\ 000 - 10\ 000 = 2000$$

$$\frac{2000}{10\ 000} \cdot 100 = 20$$

So, output increased by 20 per cent. As the number of workers stayed the same, this is also the increase in productivity.

Exercise 1

If you want to check your understanding of percentages, calculate the percentage increase in productivity if the output expands from 12 000 in year 2 to 15 000 in year 3.

Answer

$15\ 000 - 12\ 000 = 3000$

$$\frac{3000}{12000} \times 100 = 25$$

The increase is 25 per cent.

In plumbing, for example, productivity would increase if the use of new materials enabled plumbers to fix broken pipes more quickly. This would free up more time for plumbers to work on other operations and hence increase their output per hour, that is, their productivity. Productivity can increase either when work methods are made more efficient without (necessarily) the introduction of new technology, perhaps from a better organisation of the factory floor, or when new methods are introduced to the production process through the introduction of new technology – for example, when new machinery allows work to be done more quickly and with fewer mistakes. Adam Smith (1723–90), one of the founders of modern economics, claimed that increases in productivity lie at the heart of economic growth and prosperity. In his influential book *The Wealth of Nations* (first published in 1776), Smith uses the example of pin making to describe the process by which productivity can increase through a rise in the division of labour, that is, the degree to which workers divide tasks between themselves. The rest of his classic text is dedicated to describing the effect of increasing productivity on the development of markets and economic growth:

> The greatest improvement in the productive powers of labour, and the greater part of the skill, dexterity, and judgement with which it is anywhere directed, or applied, seem to have been the effects of the division of labour … To take an example, therefore, from a very trifling manufacture; but one in which the division of labour has been very often taken notice of, the trade of the pin-maker; a workman not educated to this business … nor acquainted with the use of the machinery employed in it … could scarce, perhaps, with his utmost industry, make one pin a day, and certainly could not make twenty. But in the way in which this business is now carried on not only the whole work is a peculiar trade, but it is divided into a number of branches, of which the greater part are likewise peculiar trades. One man draws out the wire, another straightens it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; to make the head requires two or three distinct operations; to put it on, is a peculiar business, to whiten the pins is another, it is even a trade by itself to put them into the paper; and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which, in some manufactories, are all performed by distinct hands, though in others the same man will sometimes perform two or three of them. I have seen a small manufactory of this kind where ten men only were employed, and where some of them consequently performed two or three distinct operations. But though they were very poor, and therefore but indifferently accommodated with the necessary machinery, they could, when they exerted themselves … make among them upwards of forty-eight thousand pins in a day.
>
> (Smith, 1937, pp. 65–6)

Question 3

What are the different tasks, outlined by Smith, involved in pin making? Why does productivity increase when these tasks are divided between workers instead of all being done by one worker, that is, when the division of labour increases?