Chapter 12

The Industrial Revolution Reconsidered

I

The Industrial Revolution has been widely considered by modern economic historians as a watershed dividing human history. The eras that preceded it are regarded as a prelude to the rapid social and economic change unleashed in Great Britain beginning with the last half of the eighteenth century. It is easy to understand this preoccupation with the Industrial Revolution. The process of sustained economic growth that historians believe began between 1750 and 1830 radically altered the manner and standard of living of Western men and women. If an ancient Greek had been miraculously transported through time to the England of 1750, he or she would have found much that was familiar. The Greek alighting two centuries later, however, would discover what would appear to be an "unreal" world in which little would be recognizable or even understandable, so much had the state of mankind been altered in that relatively brief historical time span.

What were the changes? They can be stated as follows:

1. Population growth occurred at an unprecedented rate. Demographers estimate that world population was approximately eight hundred million in 1750. It was in excess of four billion by 1980. (Coale 1974:43)

2. The Western world achieved a standard of living which had no counterpart in the past. The average citizen enjoyed luxuries which were not available to even the richest man of earlier societies. Moreover, the average length of life almost doubled in the developed countries.

3. In the Western world agriculture ceased to be the dominant economic activity; industry and service sectors of the economy replaced it in significance. This change was made possible by the tremendous increase in agricultural productivity. In the United States the 5 percent of the population engaged in agriculture could feed the other 95 percent and still have enough left over to make the United States a world leader in the export of agricultural goods. In colonial times these percentages were reversed.

4. In consequence, the Western world became an urban society with all that term implies concerning increasing specialization, division of labor, interdependence, and inevitable externalities.

5. Continuous technological change became the norm. New sources of energy were harnassed to do men's work, and new materials and substances constantly created to satisfy human wants.

While these developments are not in question, how these changes occurred, when they began, and what we mean by the term Industrial Revolution have been the subject of a substantial debate. It is the argument of this chapter that the Industrial Revolution was an acceleration in the rate of innovation, the origins of which go back well before the traditional chronology (1750–1830). It was better specified property rights (not the same thing as laissez faire) which improved factor and product markets as described in the previous chapter. The resultant increasing market size induced greater specialization and division of labor, which increased transaction costs. Organizational changes were devised to reduce these transaction costs and had the consequence of radically lowering the cost of innovating at the same time that the increasing market size and better specified property rights over inventions were raising the rate of return on innovating. It was this set of developments which paved the way for the real revolution in technology—the Second Economic Revolution—which was the wedding of science and technology. It was this later development, in the second half of the nineteenth century, which produced the elastic supply curve of new knowledge and the unprecedented developments briefly summarized above.

In order to set this story in perspective we must first review the traditional story of the Industrial Revolution and explore the nature of technological change; then we shall be in a position to examine the interrelated process of organizational change and technological development which made up the Industrial Revolution as it is defined in this chapter.

II

Historians agree that these changes in organization and technology began in Britain during the middle decades of the eighteenth century. Over the next hundred years, the population of Britain tripled; some towns grew into big cities; the average income of an Englishman more than doubled; agriculture fell from roughly one-half of the nation's output to under one-fifth; and manufacturing and services expanded to assume the farmer's former role. In the process the manufacture of textiles and iron was undertaken in steam-powered factories of greatly improved efficiency.

This combination of events has appeared more startling to the historian than it did to contemporaries. Adam Smith, writing the most important book on economics in the middle of these occurrences, did not mention them. Further, he predicted that his nation of merchants, farmers, and handcraftsmen would continue to increase its wealth at a moderate pace by further specialization and trade; in fact, national income rose at an unprecedented rate in the next eight decades.

Smith was in good company. David Ricardo suggested that rising rents would absorb any increase in productivity. In the decades immediately after Ricardo wrote, rents as a share of a rising national income fell by half. Thomas Malthus predicted that the enormous increase in population would keep wages from rising for long times above subsistence; and Karl Marx, writing at the end of the era, predicted that the lot of the worker would not improve. Instead, the share of labor income in national income rose markedly, and real wages increased dramatically. The classical economists simply failed to understand the events that were occurring around them.

It is not that all contemporaries were unaware of change occurring. Some were aware, as evidenced in Frederick Engel's *Conditions of the Working Class in England,* published in 1844. But the term "Industrial Revolution" was not popularized until Arnold Toynbee employed it in a series of lectures delivered in 1880–1881, five decades after the date customarily accepted as the end of the transformation to which it refers.

Why did most classical economists miss the Industrial Revolution while living through it? Perhaps because the significance of this century of change lies more in the analyses of historians than in actuality. Population, for instance, was growing prior to the century of Industrial Revolution; large cities existed before the industrial towns grew up; and the income of Englishmen increased prior to the birth of Adam Smith as well as during his life and the lives of other classical economists. During this period there were more and more agricultural workers in total; agriculture would not have appeared a declining industry to a contemporary observer. Large factories had existed prior to the Industrial Revolution, and steam engines had been employed in coal mines for decades before James Watt's steam engine. The fabled Watt engine was simply an improvement over the previously existed Newcomen engines. So perhaps it is not surprising that the classical economists missed the Industrial Revolution: for what was new was the magnitude of the changes, not their revolutionary character. While the average Briton marveled at the wonders of the Crystal Palace Exhibition of 1851, he would have found the transformation of the next 125 years to be simply unbelievable. And while the classic era of the Industrial Revolution was certainly an acceleration in economic change, the revolutionary transformation I described at the beginning of this chapter is predominantly a happening of the past 150 years. It was after the middle of the nineteenth century that everyday life was transformed in such a fashion that our mythical time-travelling Greek would no longer recognize earth as a familiar place.

The enormous growth in population, for instance, which began prior to the Industrial Revolution, had been transformed into a world population explosion by the middle of the twentieth century. The cause of this modern explosion has been declining mortality from infectious disease as a result of improvement in nutrition and in the environment. Similarly, an urban world is a development that has occurred during the last hundred years and is associated not so much with the industrial city as with a dramatic decline in the costs of transportation, the increase in agricultural productivity, and the agglomerative benefits of central places for economic activity. Nor does the industrial sector dominate the employment of the developed nation's labor force; services, not manufacturing, employ the vast majority of modern workers. Further, the rate of economic growth during the Industrial Revolution was not particularly impressive when compared with later eras, especially the rates achieved by more recently developing nations.

In short, our stereotyped views of the past two centuries are in need of revision. The period that we have come to call the Industrial Revolution was not the radical break with the past that we sometimes believe it to have been. Instead, as I shall show below, it was the evolutionary culmination of a series of prior events. The real revolution occurred much later, in the last half of the nineteenth century. The technological events of the Industrial Revolution period were largely independent of developments in basic science.[1] The technological events of the recent past, on the other hand, all have required major breakthroughs in science. Learning by doing can explain the technology developed during the Industrial Revolution, but only scientific experimentation can account for the development of nuclear power or the petrochemical industry. The great technological strides of the last hundred years depended upon the scientific revolution; and the combination of science and technology produced the Second Economic Revolution.

III

To understand what occurred during the Industrial Revolution it is necessary to explore the process of technological change. Most of the existing literature, concentrating on the great inventions such as Watt's steam engine, Arkwright's water frame, or Crompton's mule, ignores the day-to-day progress in technological change which produces the sustained productivity increase in economic activity; nor is it integrated into a transaction cost

[1] For a discussion of the role of science in the Industrial Revolution see Musson, ed. (1972).

framework that would permit us to understand the complex reciprocal relationship between economic organization and technical change.

From initial conceptualization to establishment of technical feasibility—that is, from invention to commercial feasibility, innovation to subsequent diffusion—is often a long and intricate process.[2] Consider, for example, the development of the steamship. Watt's steam engine was an eighteenth-century invention. Its application to water transportation occurs at the beginning of the nineteenth century. Yet we do not observe that the steamship replaced the sailing ship until the end of the nineteenth century. As late as 1880 most of the world's bulk cargo was still being carried by sailing ships. Thus, one of the most dramatic inventions took almost a hundred years to replace its predecessor.

The transformation took place only gradually because successive modifications and improvements in the reciprocating engines were required to reduce fuel consumption (and thereby increase carrying capacity) and, equally, continued improvements in the sailing ship which increased speed and reduced the size of crews allowed the sailing ship to keep pace with the steamship for most of the nineteenth century.

The process of technology improvement depends upon not only the day-to-day improvements in a new technique but also the developing human skills using the new technique. The process of learning by doing must also accompany technical change. In addition, technical changes in one area may outrun technical knowledge in other fields. We are familiar with the fact that Watt's steam engine could not be efficiently produced until Wilkinson's boring machine enabled Watts to bore precision cylinders. Even more famous is the fate of the celebrated notebooks of Leonardo da Vinci: a vast array of original ideas could not be implemented with the companion technologies of the time. Indeed, the relationship between the development of new techniques and the development of new knowledge is a major issue.

Innovations draw upon the stock of existing fundamental knowledge which men possess. That knowledge is today embodied in such formal scientific disciplines as physics, chemistry,

[2] See Rosenberg (1972) for an excellent elaboration of the incremental character of technological change.

and biology. These disciplines are of recent origin, beginning in the late Renaissance and early modern eras. It is not that man's fundamental knowledge of his environment had not expanded since neolithic times: I have discussed a number of these advances in earlier chapters. But these developments did not depend upon structured formal disciplines. We must make this distinction, because the incentives to expand pure knowledge are not necessarily the same as those that lead to practical innovation.

Historically, there has always been a gap between pure scientific knowledge and the techniques that man has utilized; indeed, until very modern times the systematic development of new knowledge was not necessary for man to make enormous progress. It is only in the last one hundred years that advances in basic knowledge are necessary to continued technological change.

What determines the rate of development of new technology and of pure scientific knowledge? In the case of technological change, the social rate of return from developing new techniques had probably always been high; but we would expect that until the means to raise the private rate of return on developing new techniques was devised, there would be slow progress in producing new techniques. And, in fact, we have observed in the previous historical chapters of this book that throughout man's past he has continually developed new techniques, but the pace has been slow and intermittent. The primary reason has been that the incentives for developing new techniques have occurred only sporadically. Typically, innovations could be copied at no cost by others and without any reward to the inventor or innovator. The failure to develop systematic property rights in innovation up until fairly modern times was a major source of the slow pace of technological change.

It is only with the Statute of Monopolies in 1624 that Britain developed a patent law. It is true that prior to that time prizes had sometimes been awarded for the development of new techniques and at times governments had subsidized men searching for new techniques. Prince Henry the Navigator, for example, called together a group of mathematicians to search for a new method of determining latitude. Governments also have often subsidized the development of military technology and provided a ready market for new weapons. But a systematic set of incentives to encourage technological change and raise the private rate of return on innovation closer to the social rate of return was established only with the patent system. It would of course be misleading to put too much stress on a single law. Eli Whitney spent a good part of his life attempting to protect his patent for the cotton gin. More important than patent law per se is the development and enforcement of a body of impersonal law protecting and enforcing contracts in which property rights are specified.

Let me restate the argument in a more rigorous fashion. Rules designed to constrain behavior with respect to an economic return to ideas face basic difficulties associated with the measurement of the idea itself. Trade mark, copyright, trade secret, and patent laws are all designed to provide some degree of exclusive rights to the inventor and innovator and have generated a controversy, spanning more than a century, over the value of patents.[3] But much of the controversy misses the point. The inability precisely to define and delineate an idea means that surrogate rules will be required; and such rules, embodying imperfect measurement and some degree of monopoly restriction, will result in real revenue losses. But as compared to no protection at all, the value of some property rights over invention is not an issue. Idle curiosity or learning by doing will produce some technological change of the type we have observed throughout human history. But the sustained devotion of effort to improve technology—as we observe in the modern world —is stimulated only by raising the private rate of return. In the absence of property rights over innovation, the pace of technological change was most fundamentally influenced by the size of markets. Other things equal, the private return upon innovation rose with larger markets. An increase in the rate of technological change in the past was associated with eras of economic expansion.

In summary, economic historians of the Industrial Revolution have concentrated upon technological change as the main dynamic factor of the period. Generally, however, they have failed to ask what caused the rate of technological change to increase during this period: often it would appear that in arguing the causes of technological progress they assume that technological progress was costless or was spontaneously generated. But in sum, an increase in the rate of technological progress will result

[3] For a review of the controversy see Machlup (1958).

from either an increase in the size of the market or an increase in the inventor's ability to capture a larger share of the benefits created by his invention.

IV

The most convincing explanation for the Industrial Revolution as an acceleration in the rate of innovation is one drawn from straightforward neoclassical theory in which a combination of better specified and enforced property rights and increasingly efficient and expanding markets directed resources into new channels. Its origins go back in time well before the traditional chronology. Let us return to the shipping illustration used at the beginning of this chapter. The competition of steam and sail in the nineteenth century really is the middle of the story. Productivity increase as a result of declining transaction costs had been going on since at least 1600, when the Dutch flute (a specialized merchant cargo ship) was used in the Baltic trade and subsequently adopted on other routes. The declining transaction costs —a result of reduced piracy, increases in size of ships, growing trade, and reduced turnaround time—led to substantial productivity growth beginning 150 years (at least) before the Industrial Revolution; and they, more than technological change, were responsible for productivity increases.[4]

What happened in ocean shipping was paralleled by equal transformation in other product and factor markets. There certainly is nothing new in this argument. It was a central part of Toynbee's celebrated lectures published in 1884. He wrote, "The essence of the industrial revolution is the substitution of competition for the medieval regulations which had previously controlled the production and distribution of wealth."[5] The same theme is picked up by Phyllis Deane and R. M. Hartwell.[6] What has been missing in the argument, however, is that while laissez faire is identified as the key to the development, the term "laissez faire" not only has misleading ideological overtones but at least in part misses the point. It is true that the decline in mercantilist restrictions including repeal or reform of the Statute

[4] See North (1968).
[5] Arnold Toynbee as quoted in Hartwell (1971:249).
[6] See Deane (1965:203) and Hartwell (1971, chapter 11).

of Artificers, poor laws, acts of settlement, usury laws, navigation acts, and so forth is part of the story. Particularly significant to the developing of more efficient markets, however, is the better specification and enforcement of property rights over goods and services; and in many cases much more was involved than simply removing restrictions on the mobility of capital and labor—important as those changes were. Private and parliamentary enclosures in agriculture, the Statute of Monopolies establishing a patent law, and the immense development of a body of common law to better specify and enforce contracts also are part of the story.[7] Laissez faire implies an absence of restraints; efficient markets imply well-specified and enforced property rights, which means the creation of a set of restraints encouraging productivity growth. The removal of restrictions widening the gap between private and social returns frequently required positive action by government—a government which we have seen was, as a result of the English revolution, oriented toward such developments. Indeed, a part of the process was the wholesale evasion of restrictions which remained on the books—and became a dead letter through lack of enforcement; such a development could only occur with the tacit approval of Parliament.

V

The Industrial Revolution, as I perceive it, was initiated by increasing size of markets, which resulted in pressures to replace medieval and crown restrictions circumscribing entrepreneurs with better specified common laws (chapter 11). The growing size of the market also induced changes in organization, away from vertical integration as exemplified in home and handicraft production to specialization. With specialization came the increasing transaction costs of measuring the inputs and outputs, as described in chapter 4. The resultant increased supervision and central monitoring of inputs to improve quality radically lowered the cost of devising new techniques.

It is in the evolution of economic organization of manufacturing that we can best observe the interplay between transaction costs and technical change which characterized the Industrial Revolution. From handicraft to putting-out system to the factory

[7] See Hartwell's discussion (1971, chapter 11).