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The Second Technological Paradigm: Railway Lines, Coal, Steel

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Abstract

The second technological paradigm (of railway lines, coal, steel) developed during the second Kondratieff wave (i.e., in the 1840s – early 1890s). This is the period of the complete victory of machine production and its powerful spread. By the end of the industrial revolution (i.e., in the 1830s), and even in the late 1840s, the main technologies and structures of the second technological paradigm (development of railway lines, rapid growth of coal mining, iron and steel production) had already formed within the first technological paradigm. During the development of the second paradigm, revolutionary changes took place in steelmaking. Machines spread everywhere. At the same time, one could observe the transition from light engineering (weaving spinning and other machines for the textile industry) to heavy engineering (rolling mills, transport machinery, etc.) which provided the basis for the development of the third paradigm.

Keywords: *railway lines, the Bessemer process, open-hearth furnace, steam engines, heavy engineering, telegraph.*

The second technological paradigm is called the paradigm of the railway lines, coal, and steel. It unfolded during the second Kondratieff wave (*i.e.*, in the 1840s – early 1890s). By the end of the industrial revolution (*i.e.,* in the 1830s), and even in the late 1840s, the main technologies and structures of the second technological paradigm had already formed within the first technological paradigm. The railway (and steamship) transport was developing very rapidly, coal mining grew everywhere and gradually began to be mechanized. Iron and steel production was also increasing, as the need for them grew every year (*e.g.,* in railway construction, machine production, *etc.*).

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The Need for Socio-Political Changes

In England (as well as later in other countries) the transition to a new paradigm required a certain modernization of significant changes in the social system, education, *etc.*

An extremely important fact was the 1832 Reform Act, the struggle for which resembled a revolution (Kertman 1979; Erofeyev 1959: 205–207; Hammond J. and Hammond B. 1947: 172–188); the crisis and depression strengthened the position of its supporters. Before this reform less than 500,000 people had the right to vote in England, and after the reform – just over 800,000 people (Meshcheryakova 1986: 300). It made parliament more responsive to the needs of business as well as the upper working class. In addition, it strengthened hopes of a large part of society for the possibility of solving conflict issues in a legal political way. One should note that this first reform of 1832 not accidentally coincided with the end of the Industrial Revolution in England. Capitalist machine production required political power which the manufacturers could influence and which would reckon with them. Rapid and rather frequent changes were required in many different areas of life (social, professional, demographic, legal, educational, foreign policy, *etc.*) in order to provide scope for economic development.

At the same time, the difficulties of transition to an industrial economy and the displacement of artisans from production, the growth of unemployment in the period of crises and depressions, harsh social legislation against the poor, hard working conditions and ruthless exploitation of children and women in factories and a number of other difficulties gave rise to the Chartist movement for the political rights of workers (from the English 'charter' – petitions which supporters of movements submitted to Parliament) in 1830 – the 1840s.

Significant changes were made in England's monetary system, the weaknesses of which were evident during the previous crisis (Trakhtenberg 1963 [1939]: 114). Another important breakthrough, the rejection of protectionism, took place somewhat later.

Thus, for the further development of Great Britain's industry and its transition to the second technological paradigm the necessary conditions emerged. The economic and political spheres were separated; private property and civil law were consolidated; census democracy as the most appropriate form of government for the new production principle was established; many obstacles of all kinds were removed and the actions of the authorities which directly hindered industry and fairer competition were discontinued. On the whole, favorable conditions for the economic development were created.

The 'Storeys' of the Industrial Economy

One should take into account that technological paradigms replace one another not instantly but gradually. On the basis of the leading paradigm there is a formation of a new technological paradigm which gradually becomes more and more important. So in the last decades of the maturity phase of the first technological paradigm the second technological paradigm started to develop. In particular, in 1830 the first Liverpool and Manchester Railway opened, its success contributed to railway construction. In 1837–1847 due to the development of railway construction which played a huge role there was a significant increase in demand for iron and other materials. From 1840 to 1845 the length of railroad tracks increased 2.5 times, and the volume of iron smelting correspondingly doubled in just two years, from 1842 to 1844 (Trakhtenberg 1963 [1939]: 150).

The second technological paradigm was developing during the second long K-wave (*i.e.,* the 1840s – early 1890s), although its last decades were already characterized by the formation of the third paradigm – heavy engineering industry. This is a period of complete victory of machine production and its powerful diffusion. It is interesting to note that by 1850 18 million residents of Britain already consumed 1.5 times more energy than 400 million Chinese (Smil 1994: 186–187; Goldstone 2014: 280). Speaking about that period, R. Jones pointed that in Britain the steam engine performed the work of 600 million people, while the actual number of employees was 4 million (Jones 1937: 351). The output of coal between 1830 and 1850 in England trebled from 15 million tons to 49 million tons (Hobsbawm 1996: 69).

The heyday of the second technological paradigm in Europe and the USA occurred later (from 1860 – the 1870s) as compared with England. Its most important factors of development (drivers) were railway construction which additionally increased demand for pig iron and steel; the emergence of methods of smelting ferrous metals (*e.g.,* the Bessemer process, open-hearth furnace, *etc.*)., and of course, the increasing demand for coal, the extraction of which was gradually mechanized in some way, although the work of the miners was and still remains one of the most difficult and dangerous. Firstly, coal was required for the rapidly growing industry, which had almost entirely switched to steam-powered machines. Due to such installation several machines were operated with the help of transmissions at once. Secondly, for the rapidly increasing volumes of metal smelting, certain grades of coal were required both for the very process of turning ore into iron and then into steel (almost all the countries abandoned the use of charcoal, except for the countries where there was plenty of wood) and for creating high smelting temperatures. Thirdly, it was required for the rapidly developing steam transport (steam ships and steam locomotives).

Fourthly, for city dwellers, as firewood was increasingly displaced from the urban economy.

Thus, one can see that the technological paradigm is a system complex of leading industries, the development of which simultaneously leads to a powerful development of other components of the technological complex. So, the development of railways (and steamship lines) required much more metal and coal; the growth of metal smelting caused a high demand for coal; the development of coal mining made it possible for land and especially sea (river) transport to pass almost anywhere in the world; the work in mines also required a lot of metal. To the aforementioned complex it is necessary to add the development of telegraph communication (the development of railways is impossible without it). Thus, at that time electricity was already being generated, and mechanical engineering was developing more and more actively. At the same time, one could observe the transition from light engineering (weaving spinning and other machines for the textile industry) to heavy engineering (rolling mills, transport machinery, *etc.*) At that period of time the chemical industry was also developing. Therefore, during the maturity phase of the second technological paradigm, there was the formation of the third technological paradigm (heavy engineering, electricity and chemical industry) within its structure.

One should also note that in addition to quantitative growth (volume growth), there was a constant qualitative growth of technologies and materials. Thus, railways, water transport, and communication technologies were repeatedly modernized due to the spread of improved grades of pig iron, steel, some other materials and more powerful mechanisms.

It is also worth pointing out that many financial innovations are closely related to technical innovations (on such a close connection see Gille 1976). For example, the widespread introduction of the telegraph and telephone radically changed the work of stock exchanges, dramatically increasing their importance, speed of work, the number of people involved in them, *etc.*, which, however, receives very little attention (see, *e.g.,* Doronin 2003: 103; Held *et al.* 2004: 225). And it is difficult to understand the development of the second technological paradigm without analyzing the powerful development of joint-stock companies, stock exchanges, a significant increase in the speed of commercial information exchange, the global expansion of stock markets, *etc.*

Great Britain had significantly outstripped the U.S. and Europe (until the 1870s – the 1880s), when the U.S. and Germany approached its level, and somewhat later overtook it. Accordingly, when in Europe the first technological paradigm was at its maturity phase and the second technological paradigm was being actively formed (together with the railway construction), in Britain the second technological paradigm reached its peak and its development began to slow down. Thus, after 1847, the development of metallurgy in Great Britain proceeded at a higher rate than in other countries, and again strengthened its

position in world production. But in the period of 1857–1866 there were significant structural changes in the development of British industry, in which not only the cotton industry was gradually losing its exceptional position, but there was also a slight slowdown in the growth of heavy industry, such as coal mining and steel smelting. On the other hand, the development of mechanical engineering (particularly iron shipbuilding, which displaced wooden ships) intensified. Great Britain was still the industrial leader of the world, but its growth rate of coal mining was already inferior to that of other countries, and the growth rate of metallurgy was inferior to that of Germany, the growth rate of the cotton and paper industry was lower than in Germany and France, and its exports were lower than in France (Mendelson 1959: 626).

The Change of the Technological Paradigm and the World-System Effect

In connection with the above, it makes sense to dwell on such an important point as the spread of technologies of the old technological paradigm within the World-System, so that the leader could actively develop the technologies of the new technological paradigm. The leader at that time was Great Britain, and the countries where these technologies being advanced before were primarily moved were Western Europe, Germany, the United States and other European countries. This makes it easier to explain Britain's sharp transition from protectionism to ideology of free trade in 1840 – the 1850s (as well as the return of Western European countries to protectionism in 1870 – the 1880s).[1]

Thus, it is very significant that from the mid-1840s, when the new technological paradigm had already strengthened in Great Britain, this country renounced protectionism and began to fight for freedom of trade, for the reduction or abolition of customs duties on goods imported into the country. Thus, in 1845–1846, duties on 400 kinds of goods were also abolished (Mendelson 1959: 429).[2] And this is no coincidence. The growth of heavy industry was largely due to domestic consumption, but the external factor also played an important role, as the modernizing European countries actively bought British equipment for the cotton industry. The fact is that, although by that time the cotton industry in other countries had begun to develop quite rapidly, it significantly lagged behind the level of Great Britain and could not compete on prices

[1] The fact is that the rapid industrial growth in various countries in the second half of the 19th century demanded the protection of domestic industry from stronger competitors. Therefore, in the last decades of the 19th century, in many countries (including Great Britain itself) there was a growing desire to help their economies with protective tariffs (which was especially evident in connection with the economic crises and difficulties of the 1870s and 1880s).

[2] In 1849–1851 there was abolished the famous Navigation Act adopted on the initiative of Oliver Cromwell in 1651, according to which the importation of goods to England could be carried only on English ships.

with English products. That is why such competition was not yet terrible for Britain. To the contrary, it played a positive role, since it created additional demand for spinning machines and looms from the rising cotton industry in Europe.

Great Britain was less dependent than before on the export of cotton fabrics, but it began to actively sell its machinery and other industrial goods to the rapidly rising and modernizing European countries. The latter needed British machinery, spare parts, iron, *etc.* Britain also supplied the world with rails and locomotives, which enabled its heavy industry to grow faster than in the rest of the world combined. Due to continuous order delays by the machine-building industry, the construction of machine-building factories began. Moreover, large amounts of the major capital spent on railroad construction in Europe and America during this decade was also 'of British origin' (Hobson 1914: 119, 120).

The market expanded to a very large extent. Thus, Great Britain was becoming not just a machine-building power, but a 'workshop of the world'.

The reduction of customs duties and the abolition of prohibitive laws greatly expanded the volume of foreign trade in the world, specialization, and contributed to the overall growth of the economy both in Great Britain and other countries. In addition to the reduction of customs tariffs there was the widespread establishment of most-favored-nation treatment (Bairoch 1989; Held *et al.* 1999: 183). The increase of free trade was in the 1850s and 1860s.

The discovery of gold deposits in California and Australia was also extremely important for the development of world (especially British) trade. From 1848 to 1857, the export of gold from these places yielded a fantastic sum for those years – 3 billion DM (approximately 150 million pounds sterling). A huge part of the sum was used to pay for British goods.[3] During the 1850s exports to Australia grew sixfold (see Tugan-Baranovsky 2008 [1894]: 141; Malakhovsky 1971: 82).

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[3] One can suppose that the amount was even higher, as other data indicate that from 1852 to 1860 gold was exported at about 100 million pounds sterling from Victoria alone, where most of Australia's gold was mined, and which resulted in the increase of the world's gold reserves by 4 % (Mosse 1974: 21).

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