THE TENTACLES OF PROGRESS

Technology Transfer in the Age of Imperialism, 1850–1940

DANIEL R. HEADRICK

New York Oxford
OXFORD UNIVERSITY PRESS
1988

8

Mining and Metallurgy

One of the charges leveled at colonialists is that they were too eager to exploit the natural resources of the colonies for their own purposes. Another is that they contributed too little to the industrialization of their colonies, or even hindered it. The mining and metallurgical industries provide evidence for both of these conflicting positions.

In the European empires of the nineteenth and twentieth centuries, there arose four major metals industries: South African gold, Malayan tin, Central African copper, and Indian iron and steel. The first of these helped turn South Africa into a settler colony and then into an independent nation. It was not, therefore, a colony in the same sense as the other lands we are studying here. The other three cases are much more comparable, both as industries and as colonial situations.

Copper, tin, and iron are ancient metals, known since prehistoric times. They are also modern metals, smelted by industrial means and for industrial purposes. Beyond the technological similarities are three very different histories. The differences are partly economic, but in the case of colonial industries, they are cultural and political as well.

One crucial difference is that the industrial nations of Europe had ample supplies of coal and iron ore and exported iron and steel products to the rest of the world. In contrast, European supplies of copper and tin were essentially depleted by the 1870s, just when the demand for these metals for electrical equipment and food canning was surging ahead. For a time, the demand for copper was met from North and South American sources, but after World War I the colonial powers were eager to develop their own supplies for political reasons. Once Cornish tin was exhausted, further tin supplies were found in only a few places: Malaya, Sumatra, Bolivia, and Nigeria. The colonial powers made every effort to develop the resources under their control.

The distribution of ores, then, accounts to a certain extent for the interest of European entrepreneurs and investors in the copper and tin deposits of the colonies, and their lack of interest in iron ores. Yet this is only the beginning of an explanation, for all three industries arose in our period. To understand this phenomenon, we must turn to the other protagonists: colonial administrators and non-European entrepreneurs. The three cases are very different.

In the Belgian Congo, the copper industry was a purely European enterprise, an exotic enclave in which Africans participated only as workers. There was simply too great a chasm between the complex and costly copper industry and the Africans' small-scale political and economic organizations. The industry was foisted upon Africa by Europeans.

Malayan tin was a simpler metal with a more complicated history. Tin ores are much easier to mine and smelt than copper. Furthermore, Malaya had attracted immigrants from China who were more enterprising and ingenious (though less organized) than Europeans. Hence, there ensued a tug-of-war between European companies and techniques and Chinese miners and their methods. Not until the 1920s did the Europeans win, briefly, with a combination of new technologies, larger investments, and political manipulation.

The case of iron and steel in India is the opposite of Congolese copper. European investors showed no interest in it. Colonial administrators were mildly interested for fiscal and military reasons but lacked the technical and managerial competence to succeed. So it was Indians who seized the opportunity to build a modern steel industry. In this case, technology was drawn from the West by Indian entrepreneurs with Indian capital. These examples therefore illustrate three very different kinds of technology transfer under colonial circumstances.

Malayan Tin and Chinese Technology in the Nineteenth Century

Tin has two main uses: one, known for thousands of years, is in the manufacture of alloys such as bronze and pewter; the other is the plating of sheet steel for cans ("tins" in British parlance) and oil drums. The latter use had to await the development of the steel, food-canning, and oil industries in the last third of the nineteenth century. Until 1871, Cornwall supplied most of the tin for Britain, then the world's foremost producer of tinplate. As demand grew, the tin mines of Cornwall were rapidly depleted. Malaya, long a supplier to the traditional tinsmiths and alloy-founders of China and India, replaced it as the world's first source of the metal for industrial uses.

From an economic point of view tin is a passive commodity, subject to a demand over which the producers have no control. In the short run the demand is price-inelastic, because the cost of tin is only a small fraction of the price of the items it is used in. At the same time it is income-elastic, because demand for tin fluctuates violently with the business cycles in the industrial countries. Hence, it is a risky business which tempts producers to form cartels in the hopes of keeping production in line with consumption. In the long run, however, the demand for tin is vulnerable to technological changes, both more efficient uses such as electroplating, which spreads it thinner, and substitution by aluminum and plastics. Though tin consumption trebled between 1871 and 1895, it only doubled from then until 1930, and only increased slightly from 1930 to 1960.[1]

The fluctuations in the world's consumption of tin parallels the fluctuations in consumption of many other tropical raw materials demanded by the industrial West. What is surprising is that the industrial West entered the tin-mining business after the demand had leveled off. In the boom period itself, before World War I, tin mining in Malaya was in the hands of Asians.

Cassiterite, the tin ore, occurs as lodes in the granite hills and in the alluvial sand and gravel washed down by the monsoon rains. For centuries, Malay farmers had panned for tin in the streams, using shallow wooden bowls called *dulangs*. They also shoveled tin-bearing soil into ditches where running water carried away the lighter sand and gravel, leaving the heavier ores on the bottom. Their methods were crude and their labor unorganized. Tin mining was essentially a part-time family occupation after the harvest was in. In the words of historian Wong Lin Ken, "They had neither the commercial shrewdness nor the aptitude for hard and sustained work so essential for the success of any business undertaking."[2]

The Chinese did, however. In the nineteenth century Malay chiefs in need of funds had encouraged the immigration of Chinese to the tin-rich regions of Perak and Selangor. These migrants displaced the Malays from tin mining because their technology and organization were particularly suited to the conditions they found. They were not miners from Yunnan, but mostly rice farmers from Kwangtung, adept at handling water and soil. These were just the skills they needed to get rid of the water that collected in open-cast mines and to wash the tin-bearing soil. To bring water to the mines, they installed bamboo pipes and dug channels from streams in the hillsides. And to pump water out of the open-cast mines they built *chia-chias*, chain-pumps powered by water wheels which could lift up to 16 tons of water per hour. These devices worked during half the year, when there was neither too little water to run the pumps, nor so much rain that the mines were flooded; together with a few simple tools–a hoe, two baskets hung from a bamboo pole, steps carved into a log–chia-chias allowed Chinese miners to dig 10 meters below the surface, much deeper than the Malays could.

Concentrating the ore was also done with wooden devices: the dulang and the *palong*, or sluice-box. Until the 1880s the ores were smelted at the mine because of high transport costs. Mine owners built small smelters of clay called Dreda furnaces, with piston pumps to provide the blast; they usually lasted one season. After midcentury, larger, more efficient brick Banka furnaces were built to last five years. In both cases, the main cost was hardwood charcoal. These devices, like those used in mining and washing the ores, were simple and required almost nothing from the outside world.

But they were labor-intensive. By all accounts, working conditions in the mines were appalling. The miners stood knee-deep in water at the bottom of pits, shoveling gravel under the tropical sun. Or they climbed up and down ladders all day, carrying loads of sand and gravel to the surface. As one Westerner commented: "A deep Chinese mine with its hundreds of coolies working far below the surface irresistibly suggests a very badly damaged ant hill."[3]

To prevent their workers from escaping, mine owners locked them up at night. More effective were opium and gambling, which the mine owners provided in order to addict their workers. The owners were also important members of the secret societies which arranged the immigration of Chinese to Malaya and controlled their lives. Chinese mining was based on the disciplined labor of the miners as much as on ingenious mechanical devices.[4]

The situation in the mining districts in the late nineteenth century was anything but static. The endemic warfare between the Malay chiefs soon involved the Chinese as well, as alliances of secret societies fought one another for control over the tin deposits. When the turbulence threatened to cut tin supplies or, worse, to attract French or German intervention, the British who controlled the Straits Settlements felt obliged to step in. Starting in 1874, they imposed residents, unofficial proconsuls, upon the various sultanates of western Malaya.

The first decades of British rule saw a tremendous upsurge in tin production, from 6,000 tons in 1871 to 50,000 in 1895.[5] By 1883, Malaya was the world's foremost tin producer. This was not due to Western enterprise or technology, despite several attempts by Western entrepreneurs to gain a foothold in the industry, but was almost entirely the result of Chinese initiatives. In this process, the rivalry between the two technological systems and the attitude of the government are especially interesting.

Almost no Westerners attempted to mine for tin in Malaya before 1874 because political conditions were too dangerous. That year the Malayan Peninsula (East India) Tin Mining Company was floated just weeks after the British takeover of Selangor. Despite official blessing, it failed a year later. This scared off others for a few years. In the early 1880s there appeared a number of other Western companies: in 1881 the French-owned Société des mines d'étain de Pérak; in 1882 the Hongkong and Shanghai Tin Mining Company and the Rawang Tin Mining Company, both owned by Western merchants in China; in 1883 the Australian-based Sandhurst Tin Mining Company and Melbourne Tin Mining Company; and in 1887 the Pahang Tin Mining Company. By the midnineties they had all failed, except for the Pahang Company.[6]

Part of their problem was difficulty controlling the Chinese miners. But the main reason seems to have been extravagant management. A British administrator, Sir Frank Swettenham, explained why:

> European mining is done by companies, and company's money is almost like government money. It is not of too much account because it seems to belong to no one in particular and is given by Providence for the support of deserving expert and often travelled individuals. Several of these are necessary to start a European mining venture and they are mostly engaged long before they are wanted. There is the manager and the sub-manager, the accountant, the engineer, the smelter. . . . Machinery is bought, houses are built, in fact the capital of the company is spent . . . and then—if things get so far—some Chinese are employed on wages or contract,

> the former for choice, to remove the overburden. After possibly a series of great hardships to the staff and disasters to the company, it is found that the tin raised is infinitesimal in value when compared with the rate of expenditure, and the longer the work goes on the greater will be the losses. This is usually discovered when the paid up capital is all but exhausted. The company is wound up and the State gets a bad name with investors, and the only people who really enjoy themselves are the neighboring Chinese miners who buy the mine and the plant for an old song and make several large fortunes out of working on their own ridiculous and primitive methods.[7]

Chinese mine owners responded to the European competition by adopting new equipment. Some was Western, such as the steam pump which Sir Hugh Low, the British resident in Perak, installed in a Chinese mine for demonstration purposes in 1877. Though a steam pump cost many times more than a chia-chia, it could pump water from a greater depth, and hence allowed mine owners to re-open mines abandoned because of flooding. By 1892 three hundred steam pumps were in use in the larger mines, while smaller mines made do with the older device.

The Chinese also innovated on their own. One invention was the *lanchut keechil,* a coffin-shaped wash box some 3 meters long. Unlike the old wash box it replaced, the lanchut keechil did not need running water but only a small pool, and it could be operated by three men. Its invention in 1891 led to a flight of mine workers away from the established mines to marginal areas with little water. Similarly, in 1892 Chinese miners introduced a system of underground mining called *ta lung,* by which parallel shafts were dug into the hillside and then the earth excavated between them until the hillside collapsed. It was a dangerous but cheap way to get ores.[8]

In Malaya, the Chinese were newcomers like the Europeans, energetic, ingenious, and greedy. Though poorer and without an industrialized homeland to supply and support them, they succeeded in countering their Western rivals with innovations that were more appropriate to the geological and labor conditions of Malaya. As late as 1914 they produced three-quarters of the country's tin, while Western firms accounted for only one-quarter.

The government of Malaya helped the Chinese mine owners with a number of measures designed to keep labor cheap and docile: encouragement to immigration, the sale of gambling and opium permits, and the discharge ticket system, which made it illegal to hire a miner before his previous contract was expired. The government also sold low-cost mining concessions and built roads and railways into the mining districts. Until 1896, as Wong points out, "probably because Western enterprise had so dismally failed to work the tin resources, the British administrators did so much to induce the entry of Chinese labour and capital into the mines that they were actually accused of being pro-Chinese by disappointed and envious Western miners."[9]

The Western Takeover of Malayan Tin

In the Sino-Western rivalry over Malayan tin, the mistakes made by Westerners were only temporary, while their advantages–access to European capital and a fast-changing technology–grew stronger with time. The first area in which Western entrepreneurs gained a foothold was smelting.

Until the 1890s the Chinese had dominated tin smelting and refining as they had mining because tin ores were smelted at the mine. Toward 1880 the older furnace types were displaced by more efficient designs. The *relau semut,* a natural-draft furnace, needed no pump and little labor but required hardwood charcoal; hence it was used in remote areas where labor was scarce and timber abundant. Elsewhere, Chinese mine owners introduced the *relau tongka,* a clay furnace standing on a three-legged iron pot imported from China, which used softwood charcoal.

Yet even in densely forested Malaya, charcoal-based metallurgy was self-defeating, because it consumed the trees on which it depended. By the 1890s charcoal metallurgy was being displaced throughout the world by coal and coke, the fuel of the West. This happened in Malaya in 1887 when the newly founded Straits Trading Company built a large coal-fired reverberatory furnace at Singapore. The new railway network made it more economical for mine owners to sell their ore to this company than to process it themselves. Furthermore, it produced a more refined tin–99.85 percent pure–which captured the European market. So efficient was the new smelter that the company eventually received shipments of ore from as far away as Australia and the Congo.

Yet the Chinese did not give up smelting without a fight. Many installed steam-powered fans on their tongka furnaces to cut labor costs. In 1897 the merchant Lee Chin Ho built a second reverberatory furnace at Penang called the Eastern Smelting Company. By

1910, it was smelting 29.2 percent of all the tin shipped from the Straits, and the following year it was bought by a British firm.[10]

Much the same happened, with some delay, in the mining industry. The Chinese share of Malayan tin production gradually declined from 78 percent in 1910 to 49 percent in 1929 and to 34 percent in 1935. The causes of their displacement by Western firms are a complex tangle of technological changes, business practices, cultural values, and government policies.

Chinese mining methods, for all their ingenuity, could only operate profitably with cheap docile labor and rich ore deposits close to the surface. In contrast, the power of Western mining techniques was their ability to extract metal profitably from ever lower grades of ore in ever less accessible deposits. At the heart of this rise in productivity was the introduction of bigger, more complex, and expensive machines, with teams of experts to run them and business organizations to finance them.

The transition from a Chinese to a Western system of mining was due, in the first place, to a geological factor: the exhaustion of the surface deposits which the Chinese were so efficient at mining, and the existence of ores which only Western equipment could reach. In 1892 the engineer F. D. Osborne, working for the Gopeng Consolidated Tin Mining Company, introduced hydraulic mining, a system first used in the gold fields of California. At a cost of 50,000 Malayan dollars (about £6,000), he had water piped a distance of 10 kilometers downhill. A monitor, or huge fire hose, ejected a stream of water at the hillside mine face, washing away some 300 cubic meters of ore-bearing soil a day. Not only was this method faster and cheaper than the Chinese ta lung system, it was also easier to use, permitting the companies that introduced it to hire Malay or Indian miners. By 1900 nine such monitors were in operation, and after that it was adopted by Chinese mine owners as well.[11]

In 1906 the engineering firm Osborne and Chappell introduced the gravel pump, which sucked not only water but also the soil from the bottom of flooded mines. As it could work to a depth of 20 meters, it allowed the reopening of flooded and abandoned open-cast mines. Being fairly inexpensive, it too quickly spread to the more prosperous Chinese mines.

Yet there remained tin-bearing soils in low-lying areas like the Kinta valley which were covered with swamps and inaccessible to all the techniques so far described. To mine them required bucket dredges, devices first used in California, New Zealand, and Australia before they appeared in Malaya. The dredge imported by the Malayan Tin Dredging Company in 1912 was a barge 46 meters long by 11 wide, with a chain of buckets that could scoop up the bottom of swamps down to a depth of 15 meters, at a rate of over 2,000 cubic meters a day, and wash out the ores on the spot. Not only did bucket dredges open up new deposits, they also made it profitable to mine lower-yielding soils than ever before. And unlike the monitors, which washed away whole hillsides and ruined the land downstream, bucket dredges were fairly gentle on the environment. However, they had to be imported from Britain at a cost of millions of Malayan dollars and were only worth using on the largest concessions. For that reason they caught on slowly. Only after World War I did firms invest in dredges and their support systems. By 1925 the forty-four dredges in operation produced 20 percent of Malaya's tin. By the late 1930s even bigger dredges, which could dig down 40 or 50 meters below the water level, accounted for half of Malayan tin production. It is these machines which eclipsed the Chinese methods.[12]

The displacement of Chinese by Western techniques accounts only partly for the displacement of Chinese by Western firms. Other causes include the business culture in the two communities and the policies of the government. Business organization was crucial because the new machines, especially the dredges, were so costly that only joint-stock companies could afford them. Here Chinese business methods were a drawback, as Wong explains:

> The Chinese were reluctant to reorganize their mining companies into joint-stock companies, without which it would be difficult to raise the large capital required to start and operate mines with the new mining techniques. In Perak the Mines Department tried in 1905 to show to the Chinese how much they stood to lose by refusing to follow the times, but it failed to break down the Chinese ignorance of the practice of joint-stock companies, as well as Chinese conservatism, individualism, and clannishness, which had all combined to make them reluctant to change their organization. In 1914 there was not a single Chinese mining company operating on the limited liability principle.[13]

The role of the British administration in all this is subject to different interpretations. Wong sees the government as favoring Western methods rather than Western people:

> Though developments in the period after the 1890's undoubtedly favoured the entry of Western capital into the tin industry, the evi-

> dence does not point to the conclusion that the changes in policy were initiated with the object of discriminating or weakening Chinese mining enterprise. The outcome of these changes was not the result of discrimination but was rather the consequence of the failure of the Chinese miners to adapt themselves to the new situation. Indeed, the administration took the trouble of demonstrating to the Chinese miners how much they stood to gain by modernizing the organization and working of their property.[14]

Li Dun-jen, on the contrary, blames the British squarely:

> How the British capitalists captured the tin enterprises from their Chinese subjects is interesting not only because it shows that in free competition the stronger capitalist often swallows the weaker one; it also indicates that the capitalists of the colonial power, supported by their own government, could easily squeeze out of business their colonial subjects, whose voice could not be heard or was ignored in the determination of official policy.[15]

Numerous policies affected the tin industry. In the 1890s legislation curtailed two of the most exploitative Chinese labor practices, the secret societies and the discharge ticket system, with the result that labor costs began to rise. Mining codes and inspectors made it more difficult for mines to dump their tailings on agricultural land downstream or to use dangerous methods like ta lung. The opium and gambling farms were abolished in 1901 and 1912, respectively. After 1906, mining properties which were not being worked could be "resumed" and sold to those possessing "sufficient capital to work with labor-saving devices." Water supplies came under government control. Concessions and mining permits were issued for larger areas to firms with more capital than previously. These policies, enacted for sound humanitarian or environmental reasons, did not hurt tin production as a whole but only the smaller, predominantly Chinese-owned mines. It is no coincidence that they appeared at the same time as Western labor-saving, capital-intensive methods.[16]

The downfall of the small Chinese mining entrepreneur came during the Depression. As long as prices were high (£313 per ton in 1926), producers could sell at a profit. When prices collapsed to £132 per ton in 1931, the Malayan government joined the Netherlands East Indies, Bolivia, and Nigeria in a cartel to restrict production. With consumption down by a third, only big firms with dredges, whose costs per ton were little more than half those of small mines, survived. The cartel accelerated a process already well underway, under the pressures of a changing technology.[17]

Opening the African Copperbelt

In some ways, the story of copper in Central Africa resembles that of Malayan tin. Like tin, it was one of the earliest metals used by humans and a basic material of industrialized societies. Impelled by a growing demand in the industrial countries for boilers and electrical wiring, Western enterprises turned Central Africa into a major supplier of copper for the world market. In other ways, however, the development of Malayan tin and African copper stand in sharp contrast. The production of copper in Africa jumped directly from a small-scale, traditional African technology to one of the most highly mechanized and large-scale industries on earth. There were no intermediate stages and no competition from any third technological system as in Malaya. Three reasons account for this. Geologically, most copper-ore deposits lie too deep and are too complex to be exploited by any but the most mechanized methods. Culturally, there were only two groups in Central Africa: the indigenous Africans and the Europeans; no other immigrants created a competing industry nor were any invited in by the colonial authorities. And finally there is the matter of timing. The effective occupation of Katanga by the Belgians and Northern Rhodesia by the British dates from the turn of the century. By the time the first copper was poured from a Western furnace in the Copperbelt in 1911, mining and smelting technology had matured, and large corporations, well supplied with funds and engineering talent, had replaced the lone prospectors and starry-eyed speculators of a previous generation.

The Copperbelt covers about 36,000 square kilometers, two-thirds of it in Katanga (now Shaba), the rest in Northern Rhodesia (now Zambia). For fifteen centuries or more, Africans mined and smelted copper there. The products they made of it–wire, weapons, utensils, and ornaments–were traded throughout southern Africa and were known to the Arabs and Europeans.

Africans dug open-cast mines 5 to 10 meters deep, occasionally as deep as 20 meters. The ore was sorted by hand and washed in streams. Smelting, a craft surrounded by mystery and ceremony, was done in small clay furnaces which produced up to 12 kilograms of copper per firing. The fuel was charcoal made from hardwood, which was rare in the savannas and had to be carried from afar by human porters. By the late nineteenth century this traditional industry had almost vanished, killed off by the slave trade and the depletion of ore deposits and hardwood trees.[18]

The ore which Africans smelted was malachite, a bright green carbonate with a copper content as high as 57 percent, which could be smelted at low temperatures without fluxes. It was produced near the surface by the weathering of other, more complex ores. Most of the deposits in Katanga were of malachite and other oxides such as azurite and cuprite with average yields of 15 percent. Far below the surface, especially in Northern Rhodesia, were copper sulphides which were harder to reach, had a lower yield, and could only be processed by industrial methods. The relationship between ores and metallurgy explains why deposits that were depleted from the Africans' standpoint looked promising to Europeans, and why Katanga was developed before Northern Rhodesia, even though it was further from the sea.

Though explorers had noted the presence of malachite outcroppings and African mine sites, the extent of Katanga's copper deposits were not readily apparent. In 1892–93 the explorer-geologist Jules Cornet noted the existence of copper ores but thought they were too remote and low-yielding to justify the expense of developing them. In 1898 Capt. Charles Lemaire, leader of another expedition, reported: "The mineral treasures which have been for a long time so liberally ascribed to Ka-Tanga did not reveal themselves to us."

Other prospectors thought differently. In 1899 Robert Williams, an associate of Cecil Rhodes, founded Tanganyika Concessions, Ltd. and obtained a concession from the British South African (Chartered) Company to prospect in Northern Rhodesia. He sent out an expedition under George Grey (brother of Foreign Secretary Sir Edward Grey) which discovered the Kansanchi deposit south of the Congo border. While there, the prospectors did a little clandestine investigation in Katanga itself. On the basis of their reports, Williams approached King Leopold of Belgium and obtained a concession from the Comité spécial du Katanga, an affiliate of the Congo Free State government, to prospect in a 150,000-square-kilometer area of Katanga. In 1901 Grey led another expedition with fifteen Europeans, fifty Africans, and two years' worth of supplies. They discovered the enormous deposits of Kolwezi, Kambove, and what was to be the Star of Congo mine. These discoveries shaped the future of Central Africa for years to come.[19]

To exploit these deposits, Tanganyika Concessions, the Comité spécial du Katanga, and the Société générale (a Belgian bank) founded a new company, the Union minière du Haut-Katanga. This arrangement was the forerunner of a long series of partnerships between the "portfolio state" (as critics called the Congo) and the Société générale, which alone accounted for 60 percent of private investment in the colony.

In 1906 the Union minière was granted a concession to mine copper in a 15,000-square-kilometer area. By the end of that year its prospectors had found over a hundred ore deposits, with yields running as high as 33 percent and an average of 12.5 percent—a rich find indeed. The problem was getting equipment in and copper out. At the time, the nearest railhead was at Broken Hill in Northern Rhodesia. When Prince Albert, heir to the Belgian throne, visited the Congo in 1908, he took a steamer to Cape Town and a train to Broken Hill, and then traveled the last 500 kilometers on foot and by bicycle. For heavier equipment, other means were used: locomobiles, huge steam tractors that slowly dragged four or five freight cars over dirt paths and made one round trip a year during the dry season.

These were temporary expedients. Under Robert Williams's direction, the railroad was extended from Broken Hill to the Congo border in 1909, and to Elisabethville, near the Star of Congo mine, in 1910. Only then could industrial mining begin in earnest.[20]

Katanga Copper, 1911–1940

Because of its different ores, the mining and metallurgy of copper are much more complex than those of tin, and they changed radically in the period 1911–40. Two kinds of metallurgy were transferred to Katanga. The first was the nineteenth-century technology of smelting the ore in a furnace, upon which the industrial complex of Lumumbashi near Elisabethville was based. The other system, in which the ores were processed by chemical and industrial means, was introduced in the 1920s to Katanga's second industrial complex at Panda-Jadotville (now Likasi).

As soon as the railway reached Elisabethville, a water-jacketed smelter was erected at Lumumbashi. In it, high-grade ores were reduced with coke imported from Europe. In June 1911, in front of Robert Williams who had come from London to witness the event, the first copper flowed from the furnace. In its first six months the smelter produced almost 1,000 tons of copper, proof that this was from the start a large-scale industry.

At first the ores were collected and washed by hand, a major bottleneck. In 1913 the Union minière planned to expand production and began to import heavy steam (and later electric) shovels capable of removing up to 1,000 tons a day, as much as 300 men with shovels. Most mines were enormous open pits in which the giant shovels filled whole trains with ore. Only at Kipushi, near the Rhodesian border, was there a mine shaft.

In the years 1913–18, as ore production increased, more water-jacketed furnaces were added to increase smelting capacity. Coal for the coke ovens was imported from Wankie in Southern Rhodesia until 1922 when a coal mine was opened in the Congo.

In 1914 the American metallurgist A. E. Wheeler, who had worked for the Anaconda and Great Falls Copper companies, surveyed an area near Panda, 150 kilometers from Elisabethville. He reported that the deposit, though extensive, contained ores that were too low-grade for the smelting process then in use. Four years later, however, Katanga's high-grade ores were already running out. The Union minière, eager to increase its share of the world copper market at a time when prices were high, decided to introduce new methods of processing medium and low-grade ores.

One such method was the gravity concentrator, which crushed the ores and separated them in shaking machines. In 1921 the company built a gravity concentration plant at Panda near newly opened mines. Another was the reverberatory furnace, which could smelt finer particles of ore than the water-jacketed furnaces and burned powdered coal instead of coke. The resulting copper matte was then passed through a Bessemer-type converter, which refined it to blister copper up to 99.4 percent pure. This degree of purity was still insufficient for electrical wiring, which must be 99.9 percent copper. Until the late twenties, Katangan copper was shipped to the United States for further refining. In 1919 the Union minière spawned a Belgian affiliate, the Société métallurgique de Hoboken, to refine Katangan copper, tin, cobalt, and uranium. By the process of thermal smelting, the Congo produced over 90,000 tons of copper in 1925, putting it in third place after the United States and Chile.[21]

Another method of concentrating the ore, flotation, extracted up to 90 percent of the ores from low-grade deposits. In this process, the ores are first ground to a fine powder, then mixed with oil and water and agitated. The ore particles stick to the oil, while other substances do not; hence the oil lifts the ore particles to the surface of the mixture, where the ore-rich froth can be skimmed off and smelted in a reverberatory furnace. Originally developed at the turn of the century to concentrate the sulphide ores of Chile and Australia, it took several years of experimentation before this method was adapted to the oxide ores of Katanga.

Metallurgists knew yet another method of obtaining copper: leaching and electrolysis. Electrolysis had long been used in Europe and America to refine impure metals. Heavy anodes of blister copper and thin cathodes ("starting sheets") of refined copper were placed in a bath of dilute sulphuric acid and copper sulphate. When a strong electrical current was applied between them, the anodes shrank as copper migrated to the cathodes and impurities fell to the bottom. The result was 99.98 percent pure copper.

With oxide ores it was possible to avoid entirely smelting by leaching—that is, dissolving concentrated ore in sulphuric acid—which then formed the electrolytic bath and deposited almost pure copper on the cathodes. The combination of leaching and electrolysis had first been used industrially in the United States and Chile during the war, and it proved to be a commercially viable way to process low-grade sulphide ores, provided there was cheap electric power. This method appealed to the Union minière because it would reduce the dependence on imported coal and the need to send copper to America for refining. However, an industrial leaching and electrolysis installation could only work in conjunction with plants to produce sulphuric acid and other chemicals. In other words, an entire integrated industrial complex would have to be built in the middle of Africa.[22]

In 1921 the Union minière built a pilot leaching plant at Panda which produced 4 tons a day. Two years later, once the technical and design problems were overcome, the company decided to create an industrial complex at Panda. It included gravity concentrators and a flotation plant to concentrate the core; four reverberatory furnaces able to produce 60,000 tons of copper a year; and a leaching and electrolysis plant at Shituru with a capacity of 30,000 tons a year. In addition, the Union minière created a number of affiliates to supply its needs: the Société générale des forces hydro-électriques du Katanga (Sogéfor), which built a hydroelectric dam on the Lifira River; the Société générale de chimie (Sogéchim) to make fatty acids, sulphuric acid, and other chemicals; the Charbonnages de la Luéna for coal; as well as a construction company, a flour mill, and other enterprises.[23]

All of this took time, and not until 1929–30 was Panda ready to produce at capacity. Between 1926 and 1930 the Union minière's production of copper rose from 80,639 to 138,949 tons a year. By then about 17 percent of its production was electrolytic. Then came the Depression, and the Union minière, a partner in a cartel called Copper Exporters, Inc., reduced its production. Most of the reduction was in thermally produced copper, however, while the more valuable electrolytic copper's portion of the company's production increased to 45 percent by 1945.[24]

Throughout this period and for years thereafter, two problems hindered the Katangan industry more than any other copper mining venture: transportation and labor. These explain why Katangan copper was no more than competitive with the United States, Chile, and Canada, despite much richer ores.

The first railway which reached Elisabethville in 1910 connected Katanga to Salisbury in Southern Rhodesia and Beira in Mozambique, a journey of 2,600 kilometers. As early as 1902 Robert Williams had sought a shorter route. The Portuguese government granted him a concession to build a railway across Angola to Benguela and Lobito Bay on the Atlantic, a distance of 2,100 kilometers. However, endless negotiations and World War I delayed construction, and the Benguela Railway did not link up to the Katangan rail network until 1931. By then the Belgians had built a third line within the Congo, but it required reloading onto river steamers at Port-Francqui and back onto the railroad at Leopoldville. These three competing railroads did little other than transport copper one way and supplies the other, and their costs were therefore high.[25]

The labor problem was, if anything, more severe. It involved four elements which could, within limits, be substituted for one another: Belgians, other whites, Africans, and machines. Their cost was only one consideration among many. Others included a racial policy which reserved the best jobs for whites, political discrimination in favor of Belgians, and a bias toward labor-saving equipment. There was, at the time, no bias toward Africans.

In the first years Belgium could not furnish enough mining and metallurgical engineers, and the technical director of the Union minière, Robert Williams, naturally sought talent where it was most abundant. The first director of the company, P. K. Horner, was an American, as were the technical managers and even the steam-shovel operators; in 1920 Americans constituted only 4.8 percent of the white workers but 42 percent of the highest-paid staff. Other mine workers and technicians came from South Africa, the Rhodesias, or Britain. The Belgians feared that the large number of Anglo-Saxons in Katanga—where, for a time, the linqua franca was English—would lead to another Jameson Raid. Hence they made every effort to Belgianize the area. By 1914, 53 percent of the Europeans were Belgians, but because of the war, the proportion dropped to 22.5 percent in 1917. After some labor troubles with white South African workers in 1918–20, the company began dismissing non-Belgians and recruiting Belgian workers and technical and administrative personnel. It did so by offering free transportation, housing, medical care, and a low-cost suburban lifestyle. In response to these efforts, the number of white employees rose from 900 in 1920 to 7,500 in 1937. Yet the company deliberately avoided attracting settlers as had happened in Rhodesia and South Africa.[26]

Toward Africans, the attitude of the Union minière and its affiliates was decidedly mixed. To begin with, Katanga was very thinly populated, with only two inhabitants per square kilometer. Hence almost all labor had to be imported, fed, and housed. Before and during World War I, when much of the mining was done by pick and shovel, the company recruited workers from Rhodesia, Ruanda-Urundi, and the lower Congo on one-year contracts. It paid them just enough to subsist and pay their taxes, but not enough to feed their families who remained home. Despite the threats of the tax collector, this system did not furnish enough workers, and for a time there was talk of bringing in 5,000 Chinese coolies. Instead, the company decided to mechanize its operations. As it explained, "In order to economize this labor force, the company is committed to develop more and more the use of every mechanical means to replace hand labor. . . . the new mines and plants are equipped according to the latest in technical progress, in order to use the minimum number of natives."[27]

Mechanization reduced the need for unskilled workers only to increase the demand for skilled ones, who were hard to find anywhere in the world. The company rejected suggestions that it train Africans: "The Congolese, too primitive, was not yet prepared to master the least skilled work. It would require a slow, patient and progressive training of 25 years before the best of them could be entrusted with machines formerly driven by Europeans."[28]

In 1928, however, the company inaugurated a new policy of "stabilization." Instead of recruiting unskilled young men on one-year contracts, it offered three-year contracts to men with families. Africans were trained as locomotive drivers, machinists, and laboratory technicians. To induce skilled workers to remain in Katanga, they were given bonuses if they married and settled in the mining towns. Housing, schools, and medical care were provided under the supervision of Belgian religious orders. As a result of this policy, the ratio of annual recruits to total African workers dropped from 96 percent in 1921–25 to 7 percent in 1931–35.[29] The treatment of African workers in the big enterprises of Katanga was pervaded with a smug paternalism, as described by a company historian:

> If the mining industry extracts from the African soil a part of the wealth it contains–much of which it discovered anyway–most of the profits it makes are directly or indirectly returned to the native populations in the most precious and durable forms: order, peace, health, education, and the possibility of progressing toward a better existence.[30]

Iron and Steel in India: The Demand Side

The story of iron and steel in the colonial world is more complex than that of copper and tin because the ferrous metals were not in demand by the West–on the contrary, the European powers supplied their colonies with ferrous metals–and therefore both the demand and the supply had to come from within the colonial world. This only happened in India.

In nineteenth-century India, ferrous metals had three uses: to supply a widespread but low-level demand among Indians for tools and hardware; to fulfill the army's requirements for weapons; and, after 1853, to meet a huge demand for iron (and later steel) rails and railway equipment. India supplied enough iron to meet the first two needs but did not develop the industry to satisfy the railway demand until World War I.

The connection between the needs of one industry and the growth of another is known as a backward linkage.[31] The success of a backward linkage in stimulating a supplier-industry in the same country as the customer-industry will depend on several factors: the existence of native entrepreneurs, their access to capital and technology, their costs compared with those of foreign competitors, and the policies of the government. When a sufficient demand exists but does not give rise to a domestic industry, there is a leakage of the backward-linkage effect to foreign suppliers, and a loss of what could have been a stimulus to economic development. All countries beginning to industrialize have been conscious of this effect and have hastened to protect their infant industries with tariffs, subsidies, or state enterprises. That India did not was just as much a political choice. Before we turn to the history of the Indian iron and steel industry, let us therefore consider the major consumer of ferrous metals in India, the railways.

During the railway booms, rails were one of the major products of the iron industry. In 1848, 27 percent of the puddled iron production of England and Wales went into rails. The new steel industries which arose in the sixties and seventies were even more dependent on their railroad customers. Until the 1890s over half the steel produced in America went into rails; in the year 1881 the rail mills used 94 percent of America's steel. If to this we add the railways' other uses of iron and steel for locomotives, rolling stock, bridges, buildings, and the like, the total is even higher; Duncan Burn estimated that in the 1860s the railways consumed two-thirds of Britain's iron production.[32]

How much iron and steel went into the railways of India? This is a difficult question, to which we can only give an approximate answer. Let us divide the Indian railways into two sorts: the standard-gauge lines which used rails weighing 42 to 50 kilograms per meter, that is, 84 to 100 tons per kilometer of single track; and the narrow-gauge lines, which used lighter rails weighing 20 to 30 kilograms per meter or 40 to 60 tons per kilometer.[33]

The number of kilometers added each year to the Indian rail network was, on average, as follows:[34]

1853–57	107	1898–1902	1585
1858–62	612	1903–7	1165
1863–67	573	1908–12	1170
1868–72	542	1913–17	917
1873–77	809	1918–22	414
1878–82	828	1923–27	674
1883–87	1436	1928–32	1047
1888–92	1293	1933–37	44
1893–97	1150		

In the boom years of railway construction between 1883 and 1912, the railways added, on the average, 1300 kilometers of track per year. Since about half the added track was standard-gauge, the railways required between 54,600 and 64,350 tons of new standard-gauge rails, plus 26,000 to 39,000 tons of new narrow-gauge rails: a total of 80,000 to 103,350 tons of new rails each year, in other words, the output of a fair-sized steel mill. Long before it had one, India was consuming enough steel to keep at least one steel mill in business.

By 1913 India had over 57,000 kilometers of track, excluding sidings. This represents approximately 4 million tons of metal for the original rails alone. To this we must add the sidings, which Morris and Dudley estimate constituted 27.5 percent of all track in 1946–47;[35] replacement rails on existing tracks; iron crossties, much used in India because of the tendency of wooden ones to rot; bridges and other superstructures, which were made of steel rather than masonry as in Europe or wood as in America; and finally, locomotives and rolling stock: all in all, 2 or 3 million more tons of iron and steel.

Given the size and growth of the Indian rail network, the world's fourth or fifth largest between 1880 and 1940, how much of its iron and steel was Indian-made? Table 8.1 gives the production of the Indian industry, in thousands of metric tons.[36]

Though India had roughly 6 percent of the world's railway mileage, it barely reached, in its best years, 2 percent of the world's pig-iron production, and less than 1 percent of the world's steel production. In ferrous metals, it was on a par with Italy and Poland, well below Luxembourg.[37]

Furthermore, India's iron and steel industry only began to meet a significant share of domestic demand in the 1930s, many decades after the railway boom was over. The railways' great demand for ferrous metals–the classic backward linkage–had leaked abroad.[38]

Table 8.1 Indian Iron and Steel Production, 1900–1940

Year	Pig Iron	Year	Pig Iron	Finished Steel	Year	Pig Iron	Finished Steel	Heavy Rails
1900	36	1914	239	68	1928	1069	280	
1901	36	1915	246	77	1929	1414	419	
1902	36	1916	249	94	1930	1194	441	
1903	36	1917	252	116	1931	1073	457	
1904	42	1918	251	132	1932	928	434	
1905	46	1919	322	136	1933	894	449	39
1906	48	1920	316	115	1934	1127	560	36
1907	40	1921	374	127	1935	1364	637	79
1908	39	1922	325	114	1936	1566	688	65
1909	40	1923	498	153	1937	1577	623	85
1910	37	1924	684	252	1938	1670	679	76
1911	50	1925	894	325	1939	1601	738	92
1912	60	1926	935	366	1940	1867	817	103
1913	60	1927	1158	436				

Since India produced little iron and no steel before 1914, 96 percent of railway supplies had to be imported: 70 percent from Britain, much of the rest from Belgium. Britain's exports of iron and steel to India rose from 82,300 to 475,500 tons a year between 1873 and 1889, paralleling the growth of railroads. By then India had become Britain's best customer for iron and steel products, and these products represented almost one-tenth of India's imports in 1913.[39]

To assert that heavy industries could have arisen somewhere, it is not enough to show that there existed a demand for their products; one must also demonstrate that their costs were low enough to withstand foreign competition, within the bounds of government support. What the historical record shows is that India became the world's lowest-cost producer of pig iron once the ferrous-metals industry got started. It was also able to produce steel, but only with the same kind of government help that other countries' heavy industries received. Let us now look at this historical record.

Indian Iron before 1914

India was famous for its iron and steel long before the coming of the Europeans. In the Middle Ages, the swords of Damascus were probably made of Indian *wootz* steel. Yet traditional Indian iron-making techniques were among the most primitive in the world. In much of India iron was made by nomadic people called Agarias who gathered ore by hand from open pits and made charcoal from trees felled nearby. They smelted the ore in small furnaces a meter or two in height, quickly made of mud and cow dung. They forced a draft into the furnace by rocking back and forth on a pair of goatskins. Since furnace temperatures were low, cast iron was unknown in India. As the ironworkers could not transport the ore or charcoal more than a few miles, they soon exhausted the local fuel and ores and had to move their works every few years.

Such primitive smelting methods kept labor productivity very low. Twenty men operating a furnace could make 50 to 100 kilograms of raw iron per day. In the early 1850s the average iron furnace in the Birbhum district of Bengal produced 24 tons of wrought iron per year; elsewhere, the average production per furnace may have been around 5 or 6 tons.[40]

This ancient iron industry sufficed for the needs of eighteenth-century Indian society, but it could not meet the British demand for weapons and other iron goods. In the course of the nineteenth century, the British tried several times to produce iron in India by European methods. Yet the methods they imported were not industrial, but the obsolescent techniques of preindustrial Europe.

The first operating European-style ironworks in India were set up in the Madras Presidency in the 1830s. The founder of the grandly titled Indian Iron, Steel and Chrome Company was a retired East India Company official named Joshua Marshall Heath. His firm's output was of high quality; in fact, some was shipped to Britain and used in the Menai and Britannia iron bridges. Its methods, however, were but minor improvements over indigenous ironworking. Nearby forests were felled for charcoal, and wood had to be imported from Ceylon at great cost. Oxen powered the bellows and other equipment and pulled the carts. Unable to compete with cheap British iron, the firm barely limped along on government grants and loans it could not pay off. Briefly revived by a group of Madras businessmen in 1853, it finally ceased production in the early 1860s and was liquidated in 1874. Such was the fate of an enterprise using seventeenth-century technology in competition with the large-scale coke-fueled ironworks of mid-nineteenth-century Britain.[41]

British interest in iron making was not quenched by the failure in Madras. The native industry of Birbhum aroused considerable attention. Despite a negative report from the Geological Survey of India, a Calcutta firm, Messrs. Mackay and Company, opened the Birbhum Iron Works in 1855 and leased the nearby forests. Its operation produced enough high-grade pig iron to drive the native ironworkers out of business. But the firm had too little capital to purchase a puddling and rolling mill, and thus it could not turn out rails, boiler plates, and other finished iron goods. Depletion of the forests soon drove up the cost of charcoal. Like Heath's operation, it succumbed to British competition.[42]

Between 1855 and 1879 the Indian government, faced with the high cost of building unprofitable strategic railways, tried to relieve the pressure on its budget and on the balance of trade by developing a domestic iron industry. In 1861 it sent Colonel Keatings of the Indian army to Sweden to study charcoal iron making–proof that the techniques had been forgotten in Great Britain. Keating brought back with him a Swedish ironmaster named Mitander. With a subsidy of 50,000 rupees (£5,000), Mitander set up a blast furnace, a charcoal oven, a rolling mill, and calcining kilns for limestone. The next year the government cut off the subsidy, the works closed, and

Mitander went home. The same fate befell a number of other attempts, at Kumaon (United Provinces), Barwai (Indore), and Nahm (Punjab), to set up small ironworks under government auspices. Finance Minister Trevelyan explained the reason for the shift in policy: "It is a misdirection of the resources of India to enter into competition with England in this branch of industry. . . . By setting up Government Iron Works we are competing, at the public expense, against the English iron trade and the English mercantile community."[43]

Up to this point, all attempts to make iron in India had involved the use of charcoal. Charcoal was much preferred to coke because it produced a better iron and India still had vast hardwood forests. Britain had switched to coke in the eighteenth century only because of the depletion of the British forests. Yet by the late nineteenth century, coke-iron was so cheap that it displaced charcoal-iron, even in well-forested countries like Russia and Canada. Looking back in the late 1880s, F. R. Mallet, superintendent of the Geological Survey of India (GSI), wrote: "Numerous attempts have been made to manufacture iron on the English system in India, but nearly all of these have been unsuccessful and have long since been abandoned; one of the chief causes of failure being the difficulty of keeping large furnaces supplied with charcoal."[44]

By the 1870s, three factors converged to make experts consider seriously the use of coke in an Indian iron industry: the long string of failures using charcoal; the phenomenal growth of coal-based iron and steel industries in Europe and America; and the discovery of important coal deposits by the GSI.

The British had known of coal deposits in India as far back as 1774. The huge Raniganj coal field, north of Calcutta, was discovered in 1815, but it served only the marginal demands of river steamers until the East Indian Railway connected it to Calcutta in 1855. In 1836 the East India Company had appointed a Committee for the Investigation of the Coal and Mineral Resources of India. Nine years later, D. H. Williams of the British Geological Survey was sent to India "for the purpose of making a geological survey of those districts in which coal fields are situated." These efforts led to the creation of the GSI in 1851, under the direction of Thomas Oldham, professor of geology at Dublin University, who discovered the Gondwana system, one of the world's largest coal reserves, in 1867.[45]

Indian coal was of poor quality. Whereas British coal averaged

68 percent fixed carbon and produced 7.8 million calories per kilogram, Indian coal had only 52 percent carbon and produced between 6.1 and 7 million calories per kilogram. Indian coal also contained between 10 and 30 percent ash, compared with 2.7 percent for British coal. Yet coal was so abundant in India and labor costs were so low that its price in Bengal fell from 10.5 rupees per ton in the 1840s to 3.4 rupees in the 1890s, while that of imported coal rose from 13.5 to 17 rupees. Indian production rose from 100,000 tons in the late 1850s to 16 million tons in 1914. Though steam engines needed twice as much Indian as British coal to produce the same energy, Indian coal was not only competitive in eastern and southern India, it was also exported to Southeast Asia. Only in western India and the Arabian Sea did transport costs favor European and South African steam coal.[46]

For steam use, different coals could be substituted for one another, depending on the price. For metallurgy, however, different coals posed different technical problems, and Indian coal was especially difficult to deal with. The first attempts to make coke-iron in India took place in 1874–75. One was a government experiment, directed by the German metallurgist Ritter von Schwartz, using iron ore from the Chanda district of the Central Provinces and coal from the Wawora coal fields; it failed because of the poor coking quality of the coal. The other attempt was a private venture. The GSI had long advocated the use of Raniganj coal to make iron, and in 1874 the Calcutta managing agency Rutherford and Company set up the Bengal Iron Works at Barakar in the Raniganj coal fields. For several years it produced 20 tons of iron a day, mostly for the government. The government refused its request for long-term contracts, loans, or a dividend guarantee, however, and when orders ceased in 1879, the works were closed.[47]

These attempts, like the many charcoal-iron projects that preceded them, were doomed by technical errors, undercapitalization, and foreign competition. Behind these business errors, however, lay a more fundamental political question. An industrial ironworks had to be large in order to take advantage of economies of scale in coke ovens, furnaces, rolling mills, and transportation. To ensure a market for its output, such a plant required a commitment of some sort from either the railways or the government. The Indian railway companies had their regular suppliers in Britain; the directors of the Bombay, Baroda and Central Indian Railway, for example, instructed their agents in India to discourage the local purchase of railway materiel.

Railway materiel constituted a major part of India's imports, fluctuating between 3 percent in the 1870s and 6.5 percent in the decade 1900–1909.[48]

The government had long subsidized the smelting of iron in India, but inconsistently. For half a century it had opted for small-scale, low-budget experiments, the purpose of which was not so much to succeed as to be terminated with minimal losses in the event of a change of policy. The government's hesitation to develop an iron industry was a result of the split system of authority between the viceroy on the one hand and the India Office on the other.

The purchase of supplies by the Indian government came under a body of regulations known as the stores policy.[49] In 1858, the secretary of state for India had ruled that Indian government purchases had to be made through the Stores Department of the India Office in London. In 1863, to encourage British manufacturers still more, Indian import duties were reduced from 10 to 1 percent on iron and eliminated on machinery. At the time they were formulated, these policies were of little consequence because there were no manufacturers of railroad supplies in India. Yet in the long run, the policy hampered the emergence of Indian industries which could have competed with the British.

Indian government officials were sensitive to the heavy burden which railroad purchases placed both on the government budget and on the balance of payments. The issue came to a head during the viceroyalty of the Marquis of Ripon (1880–83). In 1881 the government purchased the defunct Bengal Iron Works with the intention of giving it to a private firm with sufficient capital to operate it and supporting it with long-term contracts. This plan was vetoed by Secretary of State for India the Marquis of Hartington, however, so Ripon decided to operate the works as a state enterprise. Ritter von Schwartz was appointed director, and skilled workers were brought from Europe. A new blast furnace, installed in 1884, raised production fourfold to 31,000 tons of pig iron a year. A foundry turned out pipes, sleepers, bridge piles, axle boxes, agricultural implements, and other castings.

Ripon's purpose was to reduce India's trade and budget deficits by stimulating import substitution industries. In 1882 he wrote:

> The Government of India have, for sometime past, had under special consideration the importance of developing the iron industry in India. The advantages which such development would afford both to State and the public—by cheapening the cost of railway construc-

> tion and maintenance, and of works for improving the water supply; by substituting metal for more perishable materials in buildings; by reducing the home charges and their concomitant loss by exchange; by creating for the population non-agricultural employment; and by increasing the means for profitable investment of capital, are too well known to require lengthened exposition.

Nevertheless Lord Ripon was well aware of political realities, as his dispatch of January 23, 1883 indicates:

> It is, we presume, certain that the establishment of the iron and steel industry would be viewed with disfavor by the persons interested in the manufacture of these articles in England. In this connection it is by no means improbable that even the most legitimate efforts to develop and encourage local industry will be represented by those interested in the matter as though such efforts involved the adoption of a protective policy on the part of the Government of India.[50]

As often happened in that benevolent dictatorship, the government of India, Ripon's policy lasted as long as he was in office. In 1884 he was replaced by Lord Dufferin, a man more inclined to leave industry to private enterprise. In 1887 the India Office insisted that the Indian government limit to the utmost "the local purchase of building materials not produced in India, such as iron, steel, tools and plant, and especially of machinery." Even engineering firms located in India which used imported machines and materials were not considered to be bona fide Indian manufacturers; hence, they would have to bid on government contracts in London, not in India.[51]

Forbidden by the India Office to invest any more money in the Bengal Iron Works, the government sold it in 1889 to Martin and Company, a Calcutta managing agency. The government agreed to purchase 10,000 tons of iron a year for ten years, but only if it cost 5 percent less than English iron, "to disarm the home manufacturers' opposition." In 1900 the firm added a third blast furnace, raising its capacity to 75,000 tons a year. The firm now had a plant large enough to produce pig and cast iron that could compete with imports. Its production rose to 25,000 tons in 1901 and to 72,000 tons in 1914.[52] A modern iron industry had finally taken root in India, albeit fifty years later than it could have, given the country's raw materials and demand for iron. Despite the firm's new name of Bengal Iron and Steel Company, or BISCO, India still failed to produce steel.

Background of the Indian Steel Industry

During the nineteenth century, an iron industry in India seemed almost inevitable. Steel was another matter entirely. A steel mill requires costly and complex equipment, and it cannot grow from small beginnings but must be built big from the start.

The first attempt to make steel by modern methods was a military project. Since the 1890s the Indian army had imported the steel artillery shells which its ordnance factories were not equipped to make. In 1891 Maj. R. H. Mahon wrote a *Report on Cast Steel in India,* in which he advocated casting steel shells at the Cossipore Ordnance Factory. The director general of ordnance, Major General Walker, approved the idea, as did the India Office. Under Major Mahon's direction, the Cossipore factory installed a steel furnace and bar rolling mill in 1896, the first such plant in India. It had no commercial significance, however, being devoted entirely to weapons manufacture.[53]

The first commercial venture into steel making was a mill built by the Bengal Iron and Steel Company in 1905. Though it had a capacity of 20,000 tons, the firm received orders from the government for 600 tons of steel in seventy different sections, negating any economies of scale that might have existed. After only eight months the pig iron, which had too high a phosphorus content, damaged the furnaces. Having lost 500,000 rupees (£36,666) on the venture, the company shut down the mill. In 1906 the *Report of the Stores Committee* noted: "It seems improbable that any such industry can be profitable, if largely dependent on private demands, especially in view of the very considerable imports from the United Kingdom and the Continent." BISCO never again tried to make steel. In 1919, facing facts, it changed its name to Bengal Iron Company.[54]

The Indian steel industry thus began inauspiciously. It was not for lack of demand, however. In the 1870s and 1880s the railways switched to steel rails, which were safer and more durable than iron, but the Indian railway companies bought their rails in Britain. The government plant was restricted to casting shells, and private British efforts had failed to create a steel industry. The industry that finally arose was not the work of Europeans but of Indians, in particular the industrialist Jamsetji Nusserwanji Tata and the geologist Pramatha Nath Bose.

Tata, a Parsi from Bombay, had made his fortune as a cotton manufacturer after 1860. Not content to be the wealthiest industrialist in an otherwise backward nation, he actively sought to modernize India by developing technical education and the electrical power and steel industries. Tata's vision was industrial, capitalist, and nationalist. Having named one of his mills the Empress in 1877 in honor of Victoria's coronation as Empress of India, he named his next one, nine years later, the Svadeshi, or "Native Self," Mill.[55]

In the early 1880s Tata read Ritter von Schwartz's *Report on the Financial Prospects of Iron Working in the Chanda District.* Not so readily discouraged by difficulties as government officials, he sent samples of coal and iron ore from the Chanda district to be tested in Britain. When the tests proved encouraging, he went to Sir John Henry Morris, chief commissioner of the Central Provinces, to ask for a concession to mine the deposits in the area and to build a 72-kilometer-long railroad from Wawora to the nearest GIP (Great Indian Peninsula) trunk line. The request was denied, and Tata had to postpone his plans until more propitious times.[56]

Until 1899 the iron industry was located in places like Chanda and Birbhum, where surface deposits of ore had been worked for many years. Little was known of India's vast underground iron-ore deposits, largely because of government obfuscation. The GSI, in its narrow focus on coal and precious minerals, had deliberately ignored iron ore. Until midcentury, surveying was restricted to Britons. The GSI recruited its first Indian apprentice in 1873 and appointed its first Indian to a graded post in 1880. Though much scientific work was done in India, it consisted almost entirely of British scientists using India as the object of their field research.[57]

Private prospecting was discouraged until the mid-nineteenth century. By the end of the century, individuals–but not companies–could obtain prospecting licenses. Licenses were limited to a 10-square-kilometer area, and a distance of 12.8 kilometers had to separate any two prospecting areas licensed to the same individual. Then, once an area was explored, the government could auction off the mining rights to it. Based on a misguided concept of fairness, the regulations effectively discouraged even the most sanguine prospector.[58]

All this changed quite suddenly in 1899, when George Curzon became viceroy. He was determined to modernize India in order to strengthen the British Empire and counter the growing flood of manufactured goods imported from Germany and Belgium. To that end, he removed the onerous regulations which had hampered prospecting and mining. That same year, Major Mahon, now superintendent of the Cossipore Ordnance Factory, published a *Report upon the Manufacture of Iron and Steel in India,* in which he advocated a large modern steel mill in India. These two events reawakened Tata's interest in steel. On a trip to London, he visited Secretary of State for India George Hamilton, who told Tata he favored Indian industries developed with Indian capital. He also wrote Curzon: "I want to associate increased investment of British capital there with a simultaneous action on the part of the Government in developing industrial enterprise."[59]

These verbal encouragements meant that the India Office and the government of India would no longer stand in the way of Tata's plans; they did not mean that the government would help. In 1902 Tata returned to Britain and asked Hamilton for a pledge that the government would purchase some of the products of his proposed steel mill. This Hamilton refused.

While in Britain, Tata studied the iron and steel industry. He had a sharp eye for industrial machinery, as he had proved thirty years before in equipping his textile mills. This time he was looking for the best steel-making methods. He did not find them in Britain. From Britain he traveled to Germany to see the Dusseldorf Industrial Exhibition, from where he wrote his son Dorabji on September 5, 1902: "We are all surprised at the superiority and cheapness of all German machines and articles, as compared to English."[60]

From Germany Tata sailed to the United States. He had been there once before, to visit the Columbian Exposition in Chicago in 1892, and had met George Westinghouse and Senator Mark Hanna. This time he traveled to Cleveland, where Hanna showed him several steel plants and introduced him to steel company officials. In Pittsburgh he discussed the Niagara hydroelectric project with Westinghouse and visited the Homestead and Duquesne mills of the Carnegie Steel Corporation. As was evident to an astute observer like Tata, the American steel industry was then at the leading edge of this technology. Already in 1890 American Bessemer converters had an average output double that of their British counterparts. Not only were American furnaces larger, they were also pushed harder, with blast pressures almost double that of British furnaces. Because British engineers were conservative, their machines lasted longer but their products cost more. Britain was falling behind in the most basic of all industries.[61]

Among Tata's many acquaintances, the most useful was Julian Kennedy, of the metallurgical engineering firm of Julian Kennedy, Sahlins and Company. Tata asked him to design a steel mill, and Kennedy recommended the consulting engineer Charles Page Perin to look into the raw materials situation. Perin agreed to work for Tata, but first he sent his assistant, the geologist C. M. Weld, to India to prospect for ore. Back in Bombay in late 1902 Tata, exhausted from his travels, handed the steel project over to his son Dorabji. When J. N. Tata died in May 1904, the project was well underway.[62]

In the early 1900s, the metalliferous regions of India were overrun by prospectors, most of them looking for manganese. In 1903, Dorabji Tata, C. M. Weld, and J. N. Tata's nephew, Shapurji Saklatvala, began by prospecting for iron ore in the Chanda district, the area which had attracted the elder Tata's attention years before. While they were there, the commissioner of the Central Provinces, Sir Benjamin Robertson, showed them a report entitled *The Iron Industry of the Western Portion of the District of Raipur,* published in 1887 by P. N. Bose of GSI.[63]

Pramatha Nath Bose was the first Indian to occupy a graded post in the Geological Survey of India. In his youth, while a student at the University of London, he had agitated and campaigned for Indian rights. The India Office, wanting to be rid of him but having no teaching position in India, instead offered him a post as assistant superintendent in the GSI. Soon after his return to India in 1880, Bose discovered and described the iron ores of the Raipur district. At the time, this attracted no attention, and Bose turned to other tasks. While working for the GSI, he kept alive his interest in the industrialization of India, perhaps through the influence of his father-in-law, the economic historian and nationalist Romesh Chunder Dutt. In 1886 Bose wrote a pamphlet entitled *Technical and Scientific Education in Bengal.* Five years later he organized the first Industrial Conference in Calcutta and helped found the Indian Industrial Association, an affiliate of the Indian National Congress, to lobby for technical education, industrial information, and government support for new industries. He also started a soap factory and a coal mine, but they both failed, like most other Bengali industrial ventures of the time.[64]

In his 1887 report on the Raipur district, Bose had described the ores as a rich hematite containing up to 72.92 percent iron. When Dorabji Tata, Weld, and Saklatvala read the report, they decided to investigate the area. They found two hills of iron ore so pure it rang under their boots. Hearing of their discovery, Sir

Thomas Holland, head of the GSI, came and reported that the hills contained 2.5 million tons of ore with an average iron content of 67.5 percent, richer than the iron ores of Britain (28–30 percent), Germany (32 percent), the United States (45–50 percent), and even Sweden (64 percent). It was easier to mine, being found in hills rather than underground. It was also low in sulphur and phosphorus, thus easy to smelt.[65]

However, Raipur was far from any source of coal. Bose had written in his report: "A charcoal furnace on a large scale could possibly be maintained here to advantage." Tata, Saklatvala, and Weld, however, were not about to make the same mistake that had doomed so many previous experiments. What was required to make a steel mill succeed was a combination of iron ore, coking coal, flux, and water close enough to each other and to major markets to keep transport costs within reason. Raipur did not possess this combination.

The Tata family spent, altogether, four years and £35,000 looking for that combination. Their careful research, in fact, is what set them apart from all other attempts to make iron and steel in India, which had been undertaken in a cheap and haphazard manner. All previous experimenters had located their plants near promising ore deposits, then looked for fuel nearby. The Tatas reversed this process. After many tests in European and American laboratories, they realized that suitable coking coal came only from the Jharia coal fields, and that their best chance would be to find good ores near the coal fields.

Once again, it was Bose who came to their aid. In 1903 he had resigned from the GSI to protest the appointment of Thomas Holland, his junior, as director general, against the usual rules of seniority. He had then become state geologist for the Maharajah of Mayurbhanj, a small principality in Orissa. There he discovered in 1903–4 the richest hematite deposit in the world, Gurumaishini Hill.[66] In February 1904 he wrote Jamsetji Tata, telling him of the new discovery and pointing out that the Mayurbhanj deposits were closer to the Bengal coal fields than the Raipur hills. Perin, hearing of the discovery, came from New York. Dorabji Tata, Saklatvala, Weld, and Perin visited the area and decided that the Tata steel works would use Mayurbhanj ore.[67]

Having found the right combination of raw materials, the Tatas obtained something equally precious: the aid of the government. In 1905 the Department of Commerce and Industry contracted to buy

20,000 tons of steel rails a year for ten years. Furthermore, the government granted railroad connections to the East India Railway's trunk line, low freights for the steel mill's raw materials and finished products, legal assistance is obtaining land and machinery, and various other favors.

There has been some debate over the causes of the government's positive attitude toward the Tata enterprise. Certainly Lord Curzon, an imperialist more than an administrator, saw the need to strengthen the British Empire, and this required steel. Britain's commercial position in India had been eroding for some time. Already in the 1890s India had begun importing more steel from Belgium than from Britain. German steel was also penetrating the Indian market, and Sir Thomas Holland commented that unless India developed its own industry, "it will soon become as much a market for German as for British goods." The Tatas were the beneficiaries of the policy shift, as they were later to acknowledge: "The very generous concessions made to our enterprise which more than any others have made an enterprise like the Tata Iron and Steel Works possible."[68]

But first a steel mill had to be built, and for that the Tatas needed to raise money. In 1906, therefore, Dorabji Tata and Perin went to London, but they found that British bankers were reluctant to invest in a new enterprise unless they could control it. The chairman of the British Railway Board, Sir Frederick Upcott, even told Perin: "Do you mean to say that the Tatas propose to make steel rails up to British specifications? Why, I will undertake to eat every pound of rail they succeed in making."[69]

Disappointed but not discouraged, Dorabji Tata returned to India. In 1907 he issued a prospectus offering shares worth 23,000,000 rupees (£1.53 million) in the Tata Iron and Steel Company. The first stock issue sold out in three weeks, almost entirely to Indians. Part of this success was due to the sound reputation of the Tata family and its contacts with the government, which promised high returns at a reasonable risk. Part of it was the *swadeshi* movement, a popular economic nationalism which encouraged wealthy Indians to invest in Indian enterprises rather than the traditional land and jewelry; thus the Maharajah Scindia of Gwalior contributed £400,000 toward Dorabji Tata's working capital. There was also an ethnic factor at work: the Parsis, who constituted only 0.03 percent of the Indian population but were the dominant business class of Bombay, bought 36 percent of the shares of TISCO, the new Tata Iron and Steel Company.[70]

The Tata Iron and Steel Company

For the site of their steel plant, the Tatas chose the village of Sakchi (now Jamshedpur) situated between the iron deposits of Gurumaishini and the Jharia coal fields, 225 kilometers west of Calcutta. Construction began in 1908, according to plans drawn up by Julian Kennedy and Charles Perin and under the supervision of Kennedy's partner Axel Sahlin. They imported two 200-ton blas furnaces, four 40-ton open-hearth furnaces, 180 coke ovens, a steam-powered blooming mill, a rail and structural mill, and a small bar mill from Germany and the United States.[71] The first furnace was blown in December 1911 and the first steel ingots rolled in February 1912. A year later the plant began producing steel rails. The Railway Board set up a laboratory at Sakchi to test them. By 1916 TISCO was producing 10,000 tons of steel rails and sections a month.

For TISCO, World War I was a godsend. India was cut off from Germany and Belgium, and British supplies became scarce. Steel imports fell by 84 percent from 1,040,000 tons in 1913–14 to 165,000 tons in 1917–18. Imports of railway supplies fell by 93 percent. Meanwhile, the demand for steel soared as the war effort put an increasing strain on the railways and the military called for ever more munitions. Its stores policy in abeyance, the Indian government now purchased all of TISCO's output. As the Indian Industrial Commission of 1916–18 explained: "In consequence of the increased difficulties of obtaining from Europe stores for war and essential purposes, the necessity of stimulating the local manufacture of munitions became a matter of vital importance."[72]

For several years TISCO grew up in a totally protected seller's market. Though the government paid less than the market price, the lost profits turned out to be a wise investment in government goodwill for the future. No infant industry could have asked for a happier childhood. TISCO's managers, Perin, Dorabji Tata, and the economist B. P. Padshah, took advantage of the market to modernize and expand the plant. As the British Ministry of Munitions had forbidden the export of steel-manufacturing equipment during the war, TISCO turned again to American suppliers. TISCO's pro-American bias, due originally to the influence of its American engineers and managers, was reinforced by wartime necessity and the nature of the raw materials. The inspectors for the Industrial Commission who visited the plant in January 1917 wrote: "The steel works, designed and erected by Americans, possess the characteristic features of American practice—a large output and the application of labour-saving machinery to the utmost extent possible."[73]

Among the new machines imported from the United States were larger blast furnaces, Bessemer converters and open-hearth furnaces, and an electric blooming mill. Special coke ovens were designed for TISCO to produce the hard coke required by the larger furnaces. The firm also purchased nearby collieries, dolomite and limestone quarries, and iron and manganese mines. By 1916–17 they had raised the plant's capacity to 200,000 tons, while its actual output rose from 31,000 tons of steel in 1912–13 to 181,000 tons in 1917–18, more than half of India's consumption. TISCO was now the largest industrial establishment in India.[74]

To overcome the problem of poor-quality coking coal, they had to adopt the duplex process used in the mills of Gary, Indiana, and Buffalo, New York. The ore was reduced in a Bessemer converter, and the resulting steel was poured into an open-hearth furnace to remove the phosphorus introduced into it by the coke. This made the steel more expensive than either the Bessemer or the Siemens-Martin open-hearth steel produced in Europe and America.

During the war, Perin and Tata had laid plans for the "greater extensions" of their plant, designed to boost its capacity to 500,000 tons of steel a year. The necessary equipment was to be imported from the United States, and the expansion was to cost $70 million.[75] But the greater extensions took longer to build than expected. Meanwhile, peace ended TISCO's cozy monopoly of the Indian steel market. In 1921 the *Asiatic Review,* an imperialist journal, compared the Indian steel industry favorably with that of Britain, noting that the raw materials needed to make a ton of pig iron cost half as much in India as in Britain, and that Indian labor, though still inefficient, was improving. The competition, however, was no longer from British but from German and Belgian steel made from battlefield scrap at prices neither Britain nor India could compete with. Though Indian pig iron was among the cheapest in the world, Indian steel was more expensive than its competitors because of the duplex process and the overvaluation of the rupee in relation to Continental currencies.[76]

The war had swept away the traditional British beliefs in free trade and laissez-faire. As early as 1915 Viceroy Lord Hardinge admitted:

> It is becoming increasingly clear that a definite and self-conscious policy of improving the industrial capabilities of India will have to be pursued. . . . After the war India will consider herself entitled to demand the utmost help which her Government can afford to enable her to take her place, so far as circumstances permit, as a manufacturing country.[77]

And the Indian Industrial Commission concluded:

> It appears to us that, in the interests of Indian industries, a radical change should be made in the methods of purchasing in India Government and railway stores. The existing system has been handed down from a time when India was almost totally dependent upon Europe for manufactured goods; but it is unsuited to modern conditions and has had a deterrent effect on attempts to develop new industries in India.[78]

The violent swings of the postwar economy led to further policy changes. In 1920 the Stores Purchase Committee recommended that the government buy through a Stores Department in India instead of the India Office in London, and that it encourage infant industries with orders at favorable rates.[79] After the war, TISCO turned to the government for protection against its dangerous new competitors. As a result the Indian Fiscal Commission presided over by Sir Ibrahim Rahimtoola recommended "discriminating protection" in 1921. The Tariff Board, set up in 1924, turned its attention first to the steel industry. On its recommendation the Indian government passed the Steel Industry (Protection) Act of 1924, which raised duties on imported steel from 2.5 to 33.3 percent ad valorem and provided subsidies for Indian rails. The next year the secretary of state for India transferred control over stores purchases to the Indian government, which required that bids on government contracts be submitted in India and in rupees, and instructed purchase officers to prefer Indian to foreign goods. A further drop in the price of Belgian steel led to the Steel Industry (Protection) Act of 1927, which raised tariffs on Continental steel while lowering them on British steel. Meanwhile, further subsidies were granted on steel and rails.[80]

The result was to build a high wall around the Indian steel market, behind which TISCO proceeded with its greater extensions. It raised its capacity to 610,000 tons of pig iron and 580,000 tons of steel annually by the mid-1920s, five times its original capacity. When the Depression reached India in 1930, TISCO was in a good position to resist, technologically, economically, and politically. Government orders for rails dropped from 121,600 tons in 1929–30 to 37,000 tons in 1932–33. Other orders for steel also fell off. Total steel consumption dropped from 1,678,085 tons in 1929 to 823,825 in 1933. Yet it was the foreign firms that lost the most. With the aid of tariffs, TISCO increased its share of the Indian steel market from 14 percent in 1920–21 to 73 percent in 1938–39; by then it produced 99 percent of the rails purchased in India.[81] TISCO had become one of the largest and most modern steel mills in the British Empire. India had at last obtained its backward linkage by political means.

Conclusion

Since the Industrial Revolution, the mining and metallurgical industries have become too complex and large-scale to evolve gradually from the artisan to the industrial stage; Chinese tin mining in Malaya was the last successful attempt. Strictly economic considerations such as the location of raw materials, the demand for the products, and the costs of production and transportation do not suffice to account for the success or failure of metallurgical industries in the colonies. Politics and culture were just as instrumental.

Tin and copper stand in contrast to iron and steel. The world demand for tin and copper gave sufficient economic motivation for foreigners to develop these industries in Malaya and the Congo. The metals industries that arose were intrinsically part of the world economy and only accidentally part of the local ones; in other words, they were enclaves. In both cases, the technology transfer was foreign-driven, with indigenous peoples playing a very incidental role.

Yet there were also political and cultural differences between them. In Malaya, the British administration was fairly passive at first, limiting itself to imposing order, and later to supervising mining operations and preventing gross abuses. It encouraged the most efficient producers, the Chinese in the late nineteenth century, and the Europeans in the twentieth. As a result, not one but two streams of foreign technology were transferred to Malaya in competition with each other. In Katanga, only the Union minière was encouraged, or even tolerated, by the authorities. The actions of the company and those of the government dovetailed so nicely that one can speak of a corporate colonialism or "portfolio state," as opposed to the petty-capitalist colonialism of Malaya.

In India the economic motivation to create an iron and steel industry was lacking. Therefore politics and culture did not simply influence this industry, they created it. And they did so after a fairly long delay. Forty years separated the first Indian railway boom of the 1860s from the opening of a modern coke-iron industry, by which time the railways had switched to steel. From the 1880s on, when steel rails began replacing iron and railroad construction reached its peak, a modern iron and steel industry would have been viable in India. The raw materials were plentiful, as Bose showed; entrepreneurship and capital could have been forthcoming, as the Tatas proved; and the technology could have been imported as it was for the railways. What was lacking was a consistent attitude on the part of the government. Before such an attitude finally appeared, thirty years went by.

What caused such long delays? One explanation is the poverty of India, which placed obstacles in the path of industrial development. Yet poverty was no obstacle to the creation of a great rail network, nor to the rise of the cotton and jute industries. Culture has also been blamed; colonials in particular liked to dwell upon Eastern "otherworldliness" or "tradition" as obstacles in the path of "progress." Yet Indians belong to many cultures, and among them certain groups are as entrepreneurial, in the Western sense, as their European counterparts. And "Indian culture" did not prevent the rise of an indigenous cotton industry.

If culture and poverty played a part in delaying the rise of industries, it was in a distant way. As explanations, the decisions of the elite that ruled India, and the values that led to these decisions, are more specific. We have seen several. One is free trade, which the British erected into a dogma before World War I and which therefore became the bugbear of Indian nationalists. All other countries which built rail networks comparable to India's used import duties to ensure the rise and survival of their heavy industries; and in India too, those industries that finally arose required protection. The stores policy, which affected the government's own purchases, long deprived potential Indian enterprises of the surest customer they might have had. The Indian government's commitments to buy iron from BISCO and steel from TISCO are ample evidence of the impact of government purchases. Prospecting rules also delayed industrialization. The GSI, so dedicated and competent in its scientific studies and in its search for coal, showed no interest in iron, even when great deposits were discovered and published by its one Indian geologist, P. N. Bose.

Thus the delay resulted largely from deliberate government policies. But what were the motives for these policies? It would be simple to blame British industries eager to hold onto their hunting preserve, the captive market of India. Yet the rise of the Bombay cotton and the Calcutta jute industries, in direct competition with powerful British interests, casts doubt on this explanation. British industries were only one of several pressure groups that influenced government policies in India. There were others, including the viceroys and secretaries of state; the Indian Civil Service; the British business community in India; and the Indian nationalists.

India was a benevolent despotism of a peculiar sort: it had not one but two despots, the viceroy in India and the secretary of state in London, neither of whom held office for very long. Hence the policies of the Indian government moved by fits and starts, from dynamic action to near-paralysis and back. Viceroys with powerful personalities like Dalhousie, Lawrence, and Curzon could start impressive programs and accomplish much in a short time. One is tempted to agree with W. Arthur Lewis when he says: "It seems almost an accident whether the government should be helpful or adverse to development. This is true even of colonial governments. . . . Much depended on the personality of the colonial governor."[82]

At other times, a stalemate arose between the viceroy and the secretary of state. The iron industry in particular, which normally needs years to develop, fell victim to these periodic stalemates. The result was a lack of direction of which the Industrial Commission complained in these terms:

> This account of the efforts made by Government for the improvement of Indian industries shows how little has been achieved, owing to the lack of a definite and accepted policy, and to the absence of an appropriate organization of specialized experts. . . . Much valuable time has been lost, during which substantial advances might have been registered.[83]

Yet neither constitutional rigidities nor personal conflicts can account fully for the hesitancy with which the Indian government approached industrialization. The vacillations, rather, reflect a real contradiction in the British position. On the one hand the British Empire was founded on the relations between Britain and India, in which Britain supplied manufactures, transportation, administration, and defense, and in exchange India supplied tropical products and manpower. In this system other colonies formed a defensive perimeter around India and an extension of the Indo-British economic system. On the other hand, outside the British Empire there was, as Curzon and his successors realized, a world of rival nations with growing industries, powerful navies, and gangster ethics.

What India needed to participate in the defense of the empire was the very industries that would help reduce India's dependence on Britain and Britain's hegemony within the empire. It is not that the rulers of British India were confused, but that the realities of world politics presented them with an intractable conflict between the interests of Britain and those of the British Empire, both of which they were committed to defending. They responded with hesitant procrastination.

Behind the transient political appointees who ruled India stood a powerful bureaucracy, the Indian Civil Service. Drawn from the gentry of Britain, its members were educated in both the humanities and the natural sciences, and they combined the qualities of an aristocracy with those of a cultured intelligentsia. This group of men, heirs of a social class that had lost its preeminence in Britain itself to the "Manchester men" and London merchants, went to India as enlightened despots, experts in the administration of fairness, ruling over a race of simple peasants and wealthy landlords. To do so they had to withstand the pressures of commerce as well as the winds of revolution.

Neither as gentlemen nor as intellectuals did the members of the ICS have much respect for technological change per se, except insofar as it was useful. Certain technologies contributed directly to their authority and efficiency and to the perpetuation of British rule. Others brought security, comfort, and status to those who used them. Railways, telegraphs, harbors and steamships, urban amenities and, lastly, automobiles and aircraft were all of this nature. The heavy industries, in contrast, were remote, not a part of the education or experience of civil servants. Thus the poor showing of the government's efforts at founding an iron industry.

What was true of government officials was also true, in a somewhat different way, of the British business community. They were of course subject to the profit motive, but their forte was international trade; hence the Scottish domination of the Bengal jute industry–an export business—as contrasted with the Bombay cotton mills—an import-substitution activity. The metallurgical and engineering industries offered, from the point of view of British businessmen in India, less profit and more risk than investing in trade or manufacture for export. Their conservative attitude was summed up by John Keenan: "Most of them felt, like the diehard fellows with me on the boat, that Indians were all right in their place, but steel making was a cut above them. A big cut. A steel industry in India would not only compete with the English mills but it wasn't practicable. Heath had proved that."[84]

Only Indians themselves, and then only a tiny minority of Indians, found their profit motives sufficiently reinforced by nationalism to warrant taking risks in heavy industries. A steel industry, like the cotton industry before it, was more than a manufacturing process and a business: it was an import-substitution activity, in other words, a swadeshi enterprise. P. N. Bose recognized this when he wrote:

> The aggressive imperialism of modern Europe is based upon industrialism. It is chiefly in the interest of their industries, that the greater powers of the West are anxious to dominate the peoples of the East. If these peoples made a vigorous well-concerted effort to develop their resources on Western methods, and supply their own wants, their markets would cease to be exploited in the way they now are by Western manufactures, and their lands would cease to be the happy hunting ground of Western enterprise. Western imperialism would then die a natural and peaceful death at least in its present highly objectionable militant form.[85]

Here, then, is the cause of the delay. Heavy industries in India did not respond to the economic forces engendered by the railways because they were distorted by political and cultural forces. They had to await two shifts in values: on the part of the British political system, the realization that such industries would be more useful to the empire against outsiders than detrimental to Britain within it; and from the point of view of creating such an industry, the appearance of Indian entrepreneurs driven by patriotism as well as by capitalism.

Notes

1. Lim Chong-Yah, *Economic Development of Modern Malaya* (Kuala Lumpur, 1967), pp. 37–43 and appendix 2.1; Ernest S. Hedges, *Tin in Social and Economic History* (London, 1964), pp. 41–45.

2. Wong Lin Ken, "Western Enterprise and the Development of the Malayan Tin Industry to 1914," in *The Economic Development of South-East Asia: Studies in Economic History and Political Economy,* ed. C. D. Cowan (London, 1964), p. 131.

3. Lennox A. Mills, *British Rule in Eastern Asia: A Study of Contemporary Government and Economic Development in British Malaya and Hong Kong* (Minneapolis and London, 1942), p. 177.

4. On Chinese mining technology before the 1880s, see H. C. Chai, *The Development of British Malaya, 1896–1909* (Kuala Lumpur, 1964), pp. 166–74; Ooi Jin Bee, "Mining Landscapes of Kinta," in *Readings in Malayan Economics,* ed. T. H. Silcock (Singapore, 1961), pp. 351–56; Wong Lin Ken, *The Malayan Tin Industry to 1914* (Tucson, Ariz., 1965), pp. 47–60; and Lim, pp. 44–47, 120–22.

5. Lim, appendix 2.1.

6. Wong, "Western Enterprise," pp. 133–40.

7. Sir Frank Swettenham, *About Perak* (Singapore, 1893), p. 34, quoted in Lim, p. 165, and Chai, p. 50.

8. Chai, p. 167; Wong, *Malayan Tin Industry,* pp. 56–59, 196–98.

9. Wong, *Malayan Tin Industry,* p. 238.

10. Ibid., pp. 154–67, 227–29; Chai, pp. 170–71; George Cyril Allen and Audrey G. Donnithorne, *Western Enterprise in Indonesia and Malaya: A Study in Economic Development* (London, 1957), pp. 158–60.

11. Chai, p. 167; Ooi, pp. 354–56; Wong, *Malayan Tin Industry,* p. 201.

12. Wong, *Malayan Tin Industry,* pp. 200–219; Lim, pp. 49–63; Harry F. Bain, *Ores and Industry in the Far East* (New York, 1933), p. 197; B. T. K. Barry and C. J. Thwaites, *Tin and Its Alloys and Compounds* (Chichester, 1983), pp. 22–27.

13. Wong, *Malayan Tin Industry,* p. 218.

14. Ibid., pp. 237–38.

15. Li Dun-jen, *British Malaya: An Economic Analysis* (New York, 1956), pp. 50–51.

16. Ibid., pp. 51–52; Wong, "Western Enterprise," pp. 147–49.

17. On the cartel of the 1930s, see William Y. Elliott et al., *International Control in the Non-Ferrous Metals* (New York, 1937), pp. 89–106; Mills, pp. 180–83; and Li, pp. 52–56.

18. Walter Cline, *Mining and Metallurgy in Negro Africa* (Menasha, Wis., 1937), pp. 56–75; Kenneth Bradley, *Cooper Venture: The Discovery and Development of Roan Antelope and Mufulira* (London, 1952), pp. 32–36; J. Austen Bancroft, *Mining in Northern Rhodesia: A Chronicle of Mineral Exploration and Mining Development* (n.p., 1961), pp. 27–39; Charles Perrings, *Black Mineworkers in Central Africa: Industrial Strategies and the Evolution of an African Proletariat in the Copperbelt, 1911–1941* (New York, 1979), pp. 5–6; Francis L. Coleman, *The Northern Rhodesia Copperbelt, 1899–1962: Technological Development up to the End of the Central African Federation* (Manchester, 1971), pp. 170–73.

19. Simon E. Katzenellenbogen, *Railways and the Copper Mines of Katanga* (Oxford, 1973), pp. 19–24, and "The Miner's Frontier: Transport and General Economic Development," in *Colonialism in Africa,* ed. Peter Duignan and L. H. Gann, vol. 4: *The Economics of Colonialism* (Cambridge, 1975),

p. 374; Simon Cunningham, *The Copper Industry in Zambia: Foreign Mining Companies in a Developing Country* (New York, 1981), p. 31; Bancroft, pp. 48–50; Coleman, pp. 6–12.

20. A. Marthoz, *L'industrie minière et métallurgique au Congo belge* (Brussels, 1955), p. 19; R. E. Birchard, "Copper in the Katanga Region of the Belgian Congo," *Economic Geography* 16 (October 1940): 429; Union minière du Haut-Katanga, *Le Katanga, pays du cuivre* (Liege, 1930), pp. 3–5; *Union minière du Haut-Katanga,* 2nd ed. (Brussels, 1956), pp. 66–92; and *Union minière du Haut-Katanga, 1906–1956: Evolution des techniques et des activités sociales* (Brussels, 1957), pp. 11–22; Jean-Luc Vellut, "Mining in the Belgian Congo" in *History of Central Africa,* ed. David Birmingham and Phyllis M. Martin, 2 vols. (London and New York, 1983), 2: 126–62; Katzenellenbogen, "Miner's Frontier," pp. 361–75; Bancroft, pp. 46–63; Bradley, pp. 60–73.

21. R. Chadwick, "New Extraction Processes for Metals" in *History of Technology,* ed. Charles Singer et al., vol. 5: *The Late Nineteenth Century, c. 1850 to c. 1900,* pp. 72–101; V. van Lint, *Le Congo et les carrières coloniales d'ingénieur* (Brussels, 1925), p. 60; Eugène Prost, *La métallurgie en Belgique et au Congo belge, Historique–situation actuelle* (Paris, 1936), pp. 281–97; J. Quets, "Métallurgie" in *Livre blanc: Apport scientifique de la Belgique au développement de l'Afrique centrale,* Académie royale des Sciences d'Outre-mer, 3 vols. (Brussels, 1962–63), 3: 1085–1104; Perrings, pp. 31–33, 74–75, 245–48; Vellut, pp. 135–40; Union minière, *Evolution,* pp. 102–30, and *Union minière,* pp. 91, 103, 107–9, 123, 146–47, 178–79.

22. Copper Development Association, *Copper: Its Ores, Mining and Extraction* (Kendals Hall, England, 1951), pp. 15–39; Chadwick, pp. 74–84; Coleman, pp. xv–xx; Perrings, pp. 44–45; Prost, pp. 283–90; Quets, pp. 1085–91; Union minière, *Evolution,* pp. 78, 106–12.

23. Union minière, *Katanga,* pp. 5–25; *Evolution,* pp. 106, 130, 162–63; and *Union minière,* pp. 148–52, 174; Prost, pp. 286–92; Katzenellenbogen, "Miner's Frontier," p. 405.

24. Perrings, pp. 245–48; Elliott et al. pp. 412–36.

25. See Katzenellenbogen, *Railways,* passim.

26. L. H. Gann and Peter Duignan, *The Rulers of Belgian Africa, 1884–1914* (Princeton, 1979), pp. 199–200; Cunningham, pp. 32, 45–46; Union minière, *Union minière,* pp. 99–105, 112, 124–26.

27. Union minière, *Katanga,* p. 45. See also Perrings, pp. 24–31, 61–62, 90–94.

28. Union minière, *Evolution,* p. 300.

29. Ibid., pp. 220–38.

30. Marthoz, pp. 58–59.

31. See Albert O. Hirschman, *The Strategy of Economic Development* (New Haven, 1958), p. 100.

32. On this linkage effect in various industrial countries see, e.g., Duncan Lyall Burn, *The Economic History of Steel Making, 1867–1939: A Study in Competition* (Cambridge, 1940), p. 28; Peter Temin, *Iron and Steel in Nineteenth-Century America: An Economic Inquiry* (Cambridge, Mass., 1964), pp. 221–23, 274–77; Jeremy Atack and Jan K. Bruekner, "Steel Rails and American Railroads, 1867–1880," *Explorations in Economic History* 19 (1982): 339–59; Thomas Esper, "Industrial Serfdom and Metallurgical Technology in 19th-

Century Russia," *Technology and Culture* 23, no. 4 (October 1982): 593, n. 48; Patrick O'Brien, *The New Economic History of the Railways* (New York, 1977), pp. 65–66; and M. C. Urquhart and K. A. H. Buckley, eds., *Historical Statistics of Canada* (Cambridge and Toronto, 1965), p. 528.

33. Jogendra Nath Sahni, *Indian Railways: One Hundred Years, 1853 to 1953* (New Delhi, 1953), p. 72; George Walter Macgeorge, *Ways and Works in India: Being an Account of the Public Works in that Country from the Earliest Times up to the Present Day* (Westminster, 1894), pp. 270, 346, 405–406, 418; Maurice A. Harrison, *Indian Locomotives of Yesterday (India, Bangla Desh, and Pakistan)*, Part 1: *Broad Gauge* (Bracknell, England, 1972), p. 6.

34. *Statistical Abstract Relating to British India,* various years.

35. Morris David Morris and Clyde B. Dudley, "Selected Railway Statistics for the Indian Subcontinent (India, Pakistan, and Bangladesh), 1853–1946–47," *Artha Vijnana* 17, no. 3 (September 1975): 193.

36. N. S. R. Sastry, *A Statistical Study of India's Industrial Development* (Bombay, 1947), pp. 105, 111 (note: the 1900–13 figures are for the Bengal Iron and Steel Works); *Statistical Abstract Relating to British India from 1926–27 to 1935–36* and *Statistical Abstract Relating to British India from 1930–31 to 1939–40.*

37. For iron and steel statistics, see Urquhart and Buckley, pp. 484–86; U.S. Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1970* (Washington, 1975), pp. 599–600; and B. R. Mitchell, *European Historical Statistics, 1750–1970* (New York, 1975), pp. 581–88.

38. On this point see also M. D. Morris, "Toward a Reinterpretation of 19th Century Indian Economic History," *Journal of Economic History* 23, no. 4 (1963): 614–16.

39. Leland Hamilton Jenks, *The Migration of British Capital to 1875* (New York, 1927), p. 227; B. R. Tomlinson, *The Political Economy of the Raj, 1914–1947: The Economics of Decolonization in India* (London, 1979), p. 3; Burn, p. 80.

40. Sabyasachi Bhattacharya, "Cultural and Social Constraints on Technological Innovation and Economic Development: Some Case Studies," *Indian Economic and Social History Review* 3, no. 3 (September 1966): 252–53; Manoranjan Chaudhuri, *The Iron and Steel Industry of India: An Economic-Geographical Appraisal* (Calcutta, 1964), p. 30; Hitesranjan Sanyal, "The Indigenous Iron Industry of Birbhum," *Indian Economic and Social History Review* 5, no. 1 (March 1968): 101–8; John Keenan, *A Steel Man in India* (New York, 1943), pp. 16–18; M. D. Morris, "The Growth of Large-Scale Industry to 1947," in *The Cambridge Economic History of India,* vol. 2: *c. 1753–c. 1970,* ed. Dharma Kumar (Cambridge, 1983): 559–61.

41. Mahadev Govind Ranade, "Iron Industry–Pioneer Attempts," in *Essays on Indian Economics: A Collection of Essays and Speeches,* 2nd ed. (Madras, 1906), pp. 170–92; Reginald Henry Mahon, *A Report upon the Manufacture of Iron and Steel in India* (Simla, 1899), appendix 2; F. R. Mallet, "Iron" in *A Dictionary of the Economic Products of India,* ed. George Watt, 4 vols. (London and Calcutta, 1890), 4: 504; Morris, "Growth," pp. 584–85; Chaudhuri, pp. 29–30.

42. Chaudhuri, p. 30; Ranade, p. 183; Sanyal, p. 107.

43. Sunil Kumar Sen, *Studies in Economic Policy and the Development of India (1848–1926)* (Calcutta, 1966), pp. 41–42; Chaudhuri, pp. 31–33; Mallet, p. 504; Ranade, p. 187–88.

44. Mallet, p. 504.

45. India, Geological Survey, *Centenary of the Geological Survey of India, 1851–1951: A Short History of the First Hundred Years* (Calcutta, 1951), pp. 2–4; Deepak Kumar, "Patterns of Colonial Science in India," *Indian Journal of History of Science* 15, no. 1 (May 1980): 107; Bishnupada Guha, "The Coal Mining Industry" in *The Economic History of India,* ed. V. B. Singh (New Delhi, 1965), pp. 308–11; Vera P. Anstey, *The Economic Development of India,* 4th ed. (London and New York, 1952), p. 25.

46. William Arthur Johnson, *The Steel Industry of India* (Cambridge, Mass., 1966), p. 28; Guha, pp. 305–16; Sahni, p. 95; Anstey, pp. 25, 235–41, 609.

47. Ritter von Schwartz, *Report on the Financial Prospects of Iron Working in the Chanda District* (Calcutta, 1882), cited in Frank Reginald Harris, *Jamsetji Nusserwanji Tata: A Chronicle of his Life,* 2nd ed. (Bombay, 1958), pp. 150–51; Ranade, pp. 184–90; Mallet, p. 104; Chaudhuri, p. 31; Johnson, p. 9; Geological Survey, p. 27.

48. Sen, pp. 16, 46; *Statistical Abstract Relating to British India,* various years (railroad materials import statistics were discontinued after 1928).

49. A history of the stores policy can be found in India, Stores Purchase Committee, *Report of the Stores Purchase Committee,* 2 vols. (Simla, 1920–21), 1: 163–92; Sen, pp. 16, 46.

50. Sunil Kumar Sen, *The House of Tata, 1839–1939* (Calcutta, 1975), pp. 29–30.

51. Sen, *Economic Policy,* p. 19.

52. Morris, "Growth," pp. 585–87.

53. Sen, *Economic Policy,* pp. 75–76; Ranade, p. 189.

54. Daniel H. Buchanan, *The Development of Capitalistic Enterprise in India* (New York, 1934), pp. 281–84; Amiya Kumar Bagchi, *Private Investment in India, 1900–1939* (Cambridge, 1972), p. 300, n. 4; Chaudhuri, pp. 31–34; Johnson, p. 9; Keenan, p. 25.

55. Sen, *House of Tata,* p. 22.

56. Lovat Fraser, *Iron and Steel in India: A Chapter from the Life of Jamshedji N. Tata* (Bombay, 1919), pp. 10–13; Harris, p. 151; Buchanan, pp. 184–85.

57. S. N. Sen, "The Character of the Introduction of Western Science in India during the Eighteenth and the Nineteenth Centuries," *Indian Journal of History of Science* 1, no. 2 (1966): 112–22.

58. Kumar, pp. 107–8; Sen, *Economic Policy,* p. 117; Harris, p. 153; Fraser, pp. 13–15.

59. B. S. Saklatvala and K. Khosla, *Jamsetji Tata* (New Delhi, 1970), pp. 87–88; Sen, *House of Tata,* pp. 34–35; Harris, pp. 155–56.

60. Saklatvala and Khosla, p. 113.

61. J. C. Carr and Walter Taplin, *History of the British Steel Industry* (Cambridge, Mass., 1962), pp. 151–54.

62. Saklatvala and Khosla, pp. 116–18; Keenan, pp. 28–30; Harris, pp. 157–68; Sen, *House of Tata,* pp. 35–36.

63. *Records of the Geological Survey of India* 20, pt. 4 (1887): 167–70.

64. Jogesh Chandra Bagal, *Pramatha Nath Bose* (New Delhi, 1955), pp. ix–71, 103–8.

65. Harris, pp. 175–77; Johnson, p. 27; Buchanan, pp. 282–83.

66. P. N. Bose, "Notes on the Geology and Mineral Resources of Mayurbhanj," *Records of the Geological Survey of India* 31, pt. 3 (1904): 167–73.

67. Saklatvala and Khosla, p. 122; Harris, pp. 179–82; Bagal, pp. xiii–xiv, 77–78; Sen, *House of Tata,* p. 37; Fraser, pp. 30–45.

68. Samuel B. Saul, *Studies in British Overseas Trade, 1870–1914* (Liverpool, 1960), pp. 198–99; Sen, *House of Tata,* pp. 42–43; Anstey, p. 243.

69. Verrier Elwin, *The Story of Tata Steel* (Bombay, 1958), p. 35.

70. Beginning in the seventeenth century, the Parsis of Bombay had achieved wealth and entrepreneurial experience as middlemen between the British-dominated international trade and the Indian market. Ashok V. Desai, "The Origins of Parsi Enterprise," *Indian Economic and Social History Review* 5, no. 4 (December 1968): 307–18; Morris, "Growth," pp. 590–91; Johnson, pp. 30–31, 243–49; Fraser, pp. 51–54.

71. Fraser, pp. 54–64.

72. India, Indian Industrial Commission, *Report of the Indian Industrial Commission, 1916–18* (Calcutta, 1918), pp. xvii–xviii.

73. India, Indian Industrial Commission, "Confidential Inspection Notes," p. 7 in India Office Records, L/E/7/855 file 8417/15.

74. India, Department of Statistics, *Large Industrial Establishments in* India (Calcutta, 1920), p. 10; Indian Industrial Commission, p. 20; Fraser, pp. 58–86. On TISCO's coal mines see C. P. Simmons, "Vertical Integration and the Indian Steel Industry: The Colliery Establishment of the Tata Iron and Steel Company, 1907–1956," *Modern Asian Studies* 11, no. 1 (1977): 127–48.

75. Elwin, pp. 52–54; Keenan, pp. 70–71; Buchanan, p. 286.

76. "The Iron and Steel Position in India," *Asiatic Review* 17 (1921): 689–94; Carr and Taplin, p. 234; Elwin, p. 55; Buchanan, pp. 284, 293; Keenan, pp. 63–70.

77. Dispatch of November 26, 1915 to secretary of state for India, quoted in Madan Mohan Malaviya, "Note," in Indian Industrial Commission, pp. 314–15.

78. Ibid., pp. 148–49.

79. Stores Purchase Committee, 1: 20–22, 125.

80. R. S. Bisht and M. P. N. Namboodripad, "Iron and Steel Industry" in Singh, pp. 204–5; Keenan, p. 79.

81. P. J. Thomas, *India's Basic Industries* (Bombay, 1948), pp. 5–7; Sen, *Economic Policy,* pp. 119–21, and *House of Tata,* pp. 48–60; Morris, "Growth," p. 626; Buchanan, p. 292; Johnson, p. 12.

82. W. Arthur Lewis, *Tropical Development, 1880–1913* (London, 1970), pp. 27–28.

83. Indian Industrial Commission, pp. 80–82.

84. Keenan, p. 26.

85. Bagal, pp. 94–95.