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Did Globalization Aid Industrial Development in Colonial India?

A study of Knowledge Transfer in the Iron Industry

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Abstract

The paper explores the link between international economic integration and technological capability in colonial India. The example of iron industry shows that many new ideas and skills flowed into India from Europe, but not all met with commercial success. The essay suggests that in those fields in which the costs of complementary factors were relatively low, the chance of success was higher. This condition was present in the craft of the blacksmith, in which the main complementary input was craftsmanship. The condition was slow to develop in iron-smelting, where the costs of fuel, labour, capital, and carriage of ore were high in the mid-nineteenth century.

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Did colonialism and globalization aid or obstruct industrial development in nineteenth century India?[1] In historical scholarship, two models of the impact of globalization usually occur together to form what we may call the received view on this question. One of these draws a picture of an accelerated integration in commodity trade, and the other draws a picture of an obstructed or distorted integration in technological knowledge. The former model follows the neoclassical framework in suggesting that the first globalization imposed a new division of labour upon India, one that destroyed manufacturing and stimulated the production and export of primary goods.[2] By and large, the received view reads the growth implications of the pattern of change in a pessimistic vein, drawing a link between trade, 'peasantization', and underdevelopment.[3] The second model deals with construction of knowledge, skill, and capability. In this view, the colonial state, deliberately or otherwise, obstructed the development of indigenous capability. In one strand, it did so by means of a preference for technological choices that favoured expatriate capital at the cost of domestic capital.[4] In another, it did so by means of a biased system of education, the purpose of which 'was not .. transfer of Western ideas and artifacts, but .. transfer of loyalties', together with destruction of indigenous handicrafts, consequently weak market-based transfer of knowledge, and overall, the formation of an 'enclavist' industrial system.[5]

The economic history of iron and steel production in India seems to illustrate the received view particularly well. Historical scholarship on iron is well-developed.[6] Most contributors to this literature implicitly share a point of view holding that a traditional industry died out due to foreign competition, there was loss of indigenous knowledge as a result, and the modern industry using western knowledge experienced a difficult start because of obstacles posed by the colonial state.[7] Modern industrialization, in this view, became possible when the imperial government reversed its obstructive stance out of political self-interest.

By gathering primary material so far under-utilized in the scholarship, and by drawing a contrast between iron-making and hardware, the present paper offers a different understanding of the effect of economic integration on the iron industry. The interest of the paper is mainly in the nineteenth century, when European artisans and traded machinery exerted a visible influence on indigenous manufacturing practices. The paper shows that the iron industry saw both failed and successful cases of knowledge transfer. These failures and successes were not connected with the policies of the state, but with conditions of factor markets.

The alternative story consists of three propositions. First, in common with many other artisanal industries, in iron, destruction was pronounced in input manufacture (smelting) and subdued in final consumer goods (blacksmiths). In the latter case, significant instances of successful knowledge transfer can be found. Second, as one would expect in an industry in which early modern Western Europe had an acknowledged lead, there was translocation of artisanal knowledge of iron-making, mainly via migration of artisans. This process created knowledge about Indian iron in the public domain that contributed to the success of later modern firms. However, in most instances, translocation ended in commercial failure.

Third, both the success of knowledge transfer (blacksmiths), and the lack of success of knowledge transfer (smelters), can be explained with reference to a single set of variables, cost of complementary inputs. Technological choices take place within a context set by conditions of factor markets. Successful adoption of a new idea requires the costs of complementary inputs to be relatively low. In iron smelting, the principal complementary inputs were wood fuel, ore, and transportation. All of these costs were high in nineteenth century India, and rising in some cases.

Mining and mass transportation were relatively undeveloped, and costly because of the terrain. Charcoal was becoming dearer. Even labour costs turned out to be high for the smelters, due to insufficient growth of a labour market. With blacksmiths, however, the only major complementary input was skilled craftsmanship, which could be found in abundance in India. Much knowledge came in embodied in cheap tools, which were quickly adopted and reproduced. Whereas large-scale smelting was a relatively capital-intensive process, smithy was not. And therefore, cost of capital mattered little in this sphere.

The rest of the paper is divided into four sections. The next section takes a brief tour of the relevant historiography, and proposes that the interpretation of iron history developed here can be generalized to other industries, and is more consistent with concepts of globalization in economic theory and economic history. The other two sections deal with the smelters and smiths, respectively. The last section offers concluding observations and returns to the question the paper opens with.

Historiography

The motivation for the paper derives from some recent research on artisans that advance a more differentiated narrative of globalization than the received view allows for. This scholarship acknowledges that mass produced inputs such as cotton yarn suffered a quick substitution of handmade for imported machine-made product in the nineteenth century. But it points out that handloom weaving saw extensive survival in spite of the fact that imported cloth cost much less to buy. The survival is explained with reference to two factors. On the demand side, product differentiation, consumption preferences in clothing, and the availability of highly skilled craftsmanship allowed handloom weavers to continue making non-standard goods for consumer markets. On the supply side, importation of artisanal technologies embodied in tools, machines and processes, reduced costs of production, increased productivity, and enhanced economies of scope.[8]

The textile example not only qualifies the received view, but also connects better with current interpretations of globalization within economic theory and history. In the spirit of trade theories that emphasize the role of product differentiation, it is possible to suggest that differentiation and consumer preference sustained demand for specific skills, including artisanal skills.[9] The impact of imported machine-made goods was destructive upon generic industrial inputs; and muted, at times creative, upon the manufacture of non-standard niche-market consumption articles, especially those that demanded some form of craftsmanship. And in the spirit of new theories of growth, the revision proposes that knowledge spillover occurred in the course of integration in factor markets, and that, if knowledge exchange and domestic capability conflicted in some fields, there were also fields wherein they were compatible.[10]

Economic history, which shares with new theories of growth an interest in knowledge, discusses four processes by which globalization creates capability across national borders: migration of skilled individuals, foreign investment, state and institutional intervention, and trade in machinery.[11] In the early modern world, mobile knowledge relied mainly on migration of skilled artisans.[12] In the postwar world, the multinational company and partnership between domestic business and the developmental state keen to direct private technological choices have played large roles.[13] In the time spanned by these two regimes, the main channel of knowledge transfer was trade in machinery. In the case of nearly all examples of 'late' industrialization founded upon a cotton textile mill industry, the nineteenth century beginning saw importation of machinery and the foremen to operate these, and the interwar maturation saw import-substitution in personnel, machines, and spare parts. In addition to these market-mediated channels, in India, the imperial connection facilitated state-mediated knowledge transfers as well; the major instances studied include the stationary steam engine, the telegraph, engineering education, and the railways.[14]

The meanings historians of India draw from these examples vary, however. Railways greatly reduced costs of bulk transportation. Did it also foster knowledge transfer? In one view, the buy-British policy followed in the procurement of railway rolling stock in the prewar phase restricted the backward linkages of railway development.[15] In a more positive view, the spillovers of railways were significant, if not on equipment, on construction; and they were increasing, as the British standards were modified in favour of the more practicable Indian ones.[16] The cotton textile mill industry was built with the help of Lancashire machinery, technical manpower, and standards. Persistence with British standards has been seen in one interpretation to have led to a dysfunctional regime in spinning in the late nineteenth century.[17] On the other hand, the close contact between Bombay mills and Lancashire machines also enabled a quick and successful diversification into weaving in response to this problem. As I mentioned above, import substitution in machinery, parts, and manpower occurred too. The 'Indianization' of the cotton mill supervisory staff in the interwar period represents a successful and somewhat under-researched case of capability building.[18] Such cases were not numerous. A recent survey of technological choices in private manufacturing attributes conservative decisions and the restrained manner in which capability building occurred to risk aversion, rather than the actions of the state.[19]

If we consider these examples collectively, globalization would seem to have had a mixed and differentiated effect on Indian industrial capability. Commodity and technology flows weakened some traditional occupations, foreclosed some potentially beneficial choices, and strengthened other spheres of operation by stimulating learning and expanding choices. The present paper is an attempt to read the history of the iron industry in colonial India in order to develop a broader understanding of why the impact of globalization was necessarily variegated.

The textile example hints at a reason why it was. Handloom weavers, protected by market segmentation, gained from globalization because new knowledge augmented an already rich resource, their craft skills. In the case of cotton mills, the cost of cotton was unassailably low in India, costs of machinery were brought down via integration of Indian port cities with the British economy especially after the Suez Canal opened, and costs of capital were kept manageable by institutional means adopted by merchant communities. New knowledge could attain success here. In short, the nature of the impact varied according to costs and availability of other factors of production. Iron illustrates this very point.

Artisanal smelting

In the prelude to the Industrial Revolution, iron-making developed in contact with the principal user industries. In early modern England and Wales, clusters of bloomery located near sources of fuel and ore served water-powered forge shops in the neighbourhood. They supplied agricultural tools, construction material, consumer articles, and machine parts. Eventually, ore was imported from overseas. In India, in contrast, iron-making retained its links with the mining of ore, and concentrated in regions that had supplies of iron ore and charcoal occurring together. But these regions did not usually have large and diversified hardware industries, or a concentration of diverse users.[20] This close contact between occurrence of ore and smelting imposed certain characteristics upon the conduct of the industry.

First, the average furnaces in early nineteenth century India were small in capacity relative to those in early modern England and parts of western Europe. The actual furnace size varied between regions within India, but even the largest did not reach 100 tons. In the 1630s, an average furnace in the Midlands made 350-400 tons of finished iron annually.[21] The largest furnaces in India were located in Malabar, and were, if operated at full capacity, capable of 90 tons of sponge iron.[22] In 1838, an average furnace of permanent construction in western India manufactured about 16 tons of wrought iron each. Some of the permanent furnaces in Birbhum in eastern India were capable of producing 34 tons of sponge iron, or 24 tons of bar iron.[23] The capacity of the semi-permanent furnaces commonly set up in central, eastern, and northern India was smaller, and rarely exceeded 2 tons of wrought iron a year, given the extremely small output per charge.[24] One authority observes that a permanent furnace in Birbhum that employed 100 persons might produce half a ton of bar iron per person.[25] The actual average should be higher, for many of these workers were employed part-time. Elsewhere, I have assumed an average output per person of 4 tons of wrought iron a year, to estimate possible production levels in the early nineteenth century.[26] The number is a plausible one.[27] The true average cannot be precisely estimated because the relationship between labour-intensity and furnace size is unclear. It cannot be substantially higher, however, for in the mid-nineteenth century, by far the more common type was the semi-permanent furnace.

Second, evidence of long-distance maritime trade in iron goods remains scarce. The few references available in the early modern period yield a low figure for export, not exceeding a few tons.[28] Equally scarce are references to an extensive inland trade in ores. Charcoal, being brittle, is not a good material for long distance trade. There is mention of a trade in ores and bar iron in Birbhum, but it was conducted by small-scale itinerant operators confined in a small region.[29]

The infrequent occurrence of trade can be explained with reference to the enormous cost of carriage that would have to be paid for any ore taken from the main source regions. An 1830s article urging European capitalists to settle in the out-of-the-way Khasi hills and make iron using local resources, mentioned that transportation accounted for two-third of the final price of iron ore sold only a short distance away.[30] Third, possibly because a large market for ore could not be found, mining of ore occurred on a small scale, on the surface, and frequently by the smelters. All of these would point to the close contact that smelting maintained with ore regions. In turn, the smelters supplied a market located within close proximity, usually for agricultural tools. The smelter-cum-smith recruited workers from a few families, and did not target markets that could offer economies of scale, such as, construction, shipping, and machinery. Fourth, there is a surprising lack of evidence suggesting inter-regional exchange in technological knowledge. The major centres of the industry appear to have been self-contained knowledge worlds, with the result that a large dispersion in furnace type and size persisted until the last quarter of the nineteenth century, when all the segments of indigenous iron-making were in decline.

The exception to this pattern was crucible steel connected with weaponry, which was an urban industry that served an urban clientele. This industry mainly used wrought iron to make steel, and did not usually make iron from ore. Similarly, sword polishers used recycled old material. Both groups depended on traded material and served relatively rich buyers. By the most generous estimate, the net demand for crucible steel due to weaponry could not exceed a few hundred tons a year.[31] Although specialized, it was this article that commanded the greatest curiosity among European observers in the late eighteenth century.[32]

Snapshots of the domestic artisanal manufacture of iron in the nineteenth century suggest a predominance of semi-nomadic itinerant communities who performed smelting in the ore regions. Figure 1 illustrates the typical modes of working. Groups such as these tended to be itinerant for two reasons, charcoal had to be procured from a wide area. And being sometimes blacksmiths themselves, their market was dispersed over many villages. An interesting description of ‘the Taremook, or wandering blacksmith’, of unspecified provenance within the Deccan, occurs in a mid-nineteenth century report on communities that were usually migratory. They travelled in groups of families, settled on the outskirts of a large village for a few months, performed smelting and iron-work, and were not known to own land.[33] Descriptions in the second half of the nineteenth century suggest a somewhat more sedentary character of the industry. The people who called themselves Agaria in central India, Aguriah in eastern India, and the Lohars of western, central and northern India were ordinarily engaged in iron. Some members of these communities worked as smelters as well as smiths.[34] Elsewhere, they were integrated in the peasant village.[35] The village Lohar was paid by an allowance of grain. Many Lohars also cultivated land. By and large these village smelters-cum-smiths fashioned their own tools of the trade.[36] In some cases, mining was done by a distinct group of people. However, there is evidence also of the smelters mining iron themselves, especially among the Agarias. In nineteenth century ethnographic material, we also come across rural smelting communities that claimed to have descended from a tradition of sword-making.[37] But such instances were rare.

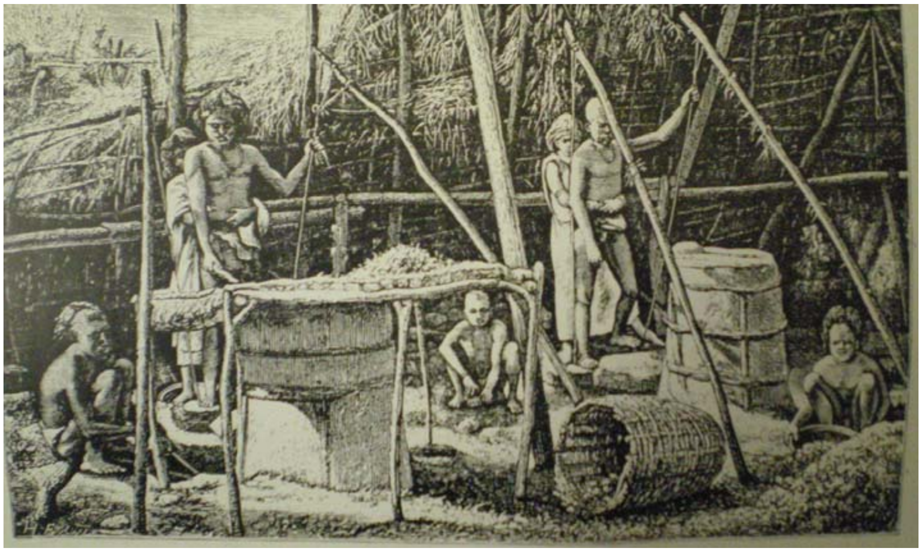

Figure 2. ‘Iron-smelters of Palamau’

Source: Valentine Ball, *Jungle Life in India*, 1880, reproduced in Verrier Elwin, *The Agaria*, Oxford, 1942.

The world of indigenous artisanal smelting declined after the entry of Swedish and British iron in India in the nineteenth century. The decline, however, was a protracted one. Until the railway network became sufficiently dense, engineers in the army and in the civil departments sometimes procured locally made iron to ‘work up into tools, straps, bolts, &c.’.[38] As the railways spread into the interior, the practice stopped. Beginning with heavier goods such as complete iron roofs and bridges, and pig iron, imports diversified into goods that competed with domestic products directly.

In the middle of the nineteenth century, iron blooms used by the north Indian Lohar came from the Central Provinces. In 1908, imported bar iron had completely replaced the local raw material. Local iron-making, such as the early nineteenth century enterprises observed by Thomas Oldham, maintained only ‘a precarious existence’ in the hills and had disappeared from the plains.[39] The country smelter ‘usually has his fields and only devotes a fraction of his time to his craft.'[40] The soft iron used by the Kanpur Lohars was called *suli*, 'the word is thought by some people to be a corruption of Swedish'. In the mid-nineteenth century, there were 160 furnaces in the Bhandara region of central India. There were scarcely any left in 1908.[41] In iron areas that were located far away from the railway line, a few furnaces continued to function, sometimes sponsored by the zamindars in whose territory the mines occurred and who were the main buyers of the goods. The relationship between the zamindars and the smelters was not a happy one, however. The more opportunities there were for trade, the keener was the zamindar to squeeze the smelter. Falling custom pushed the earnings of the semi-nomadic iron-makers of Gond and Agaria origin to very low levels. When fully employed, they hoped to earn an income that was lower than the average wage of the agricultural labourer.[42] The relatively larger-scale workshops of Southern India and those of Birbhum suffered an earlier and quicker decline, almost certainly due to scarcity of wood fuel.

The obvious reason for decline was that the cost of Indian iron had been too high. About 1900, the average price of country iron per ton (based on six samples from Santal Parganas, Bundelkhand, Bhandara, Chhattisgarh, Garhwal, and Konkan) was Rs. 187. And the average of two samples of iron of English manufacture Rs. 131.[43] The price difference between domestic and imported iron had been wide in the eighteenth century as well.[44] In these times, the difference could not reflect relative levels of mechanization. Both knowledge worlds relied fundamentally on manual labour, charcoal, and bloomery type furnace. And yet, mainly due to differences in scale, labour productivity was low, and the cost of conversion of ore into finished iron, as well as energy-intensity, were high in India. An exact measure of relative labour productivity cannot be constructed, not least because many Indian smelters were part-time workers. I have discussed above the very small capacity of the average furnace. Nineteenth century observers familiar with European practice noted 'the immense disproportion between the time and labour expended and the out-turn' of iron in such small furnaces in India.[45] In seventeenth century England, the average quantity of charcoal used was 2.5 loads per ton of pig iron.[46] Taking a load to measure approximately 15 cwt of charcoal, we get a charcoal-iron ratio of 1.9:1. In the mid-nineteenth century, the most efficient artisanal iron-making in Europe, the Swedish forge, turned out a ratio of 1.3:1, and the least efficient, the Catalan forge, 7:1.[47] Traditional smelting in Bundelkhand, based on a description of a mid-nineteenth century source, used a charcoal-iron ratio of approximately 8:1.[48] In the forests of Chota Nagpur, the ratio was about 5.3:1.[49] In Bhandara region of central India, the ratio was 6.3:1.[50] Likewise, the standard ore-bar conversion ratio of 8-10:1 compared poorly with European averages.[51]

In addition to higher conversion cost to begin with, the Indian smelter had to contend, like charcoal-iron makers elsewhere, with rising cost of fuel.[52] Where forests had once been plentiful, they were either beginning to become scarce or protected. When British rule began in the Kumaon Himalayas, iron mines were in existence in the Ramgarh region. Bishop Heber was informed in 1824 that a good deal of iron ore was found in the neighbourhood of Almorah, 'which the inhabitants of the small village were employed in washing from its grosser impurities, and fitting it to be transported to Almorah for smelting.'[53] In the 1820s, the headman of a community called Agaris had taken a lease to work all the mines in the region. It appears that most of these works were abandoned, and the Agaris left the region when easily transportable charcoal ran out of supply. From the 1860s, the central Indian Lohar had to pay a large fee to the Forest Department. Oldham estimated that 40 furnaces in the Nimar district drew their fuel supplies from 350 square miles of forest. The number is possibly an overestimate, for elsewhere, we find a figure of 30 acres for one furnace. Still, the enormity of the charcoal constraint can be gauged from these numbers. Not surprisingly, 'the lohars complain that charcoal grows dearer and dearer.'[54]

Much before the decline of indigenous smelting became pronounced, another form of artisanal iron-making was trying to establish itself in India. In the nineteenth century, artisan-entrepreneurs having some connection with the East India Company tried to erect viable iron shops after the English model. They were driven by a conception of comparative advantage that was not totally unrealistic. In this view, 'they have labour cheap, and they have abundance of ore cheap, but they want skill and capital.'[55] These entrepreneurs expected that with a change in scale they could bring down average costs substantially.

Despite the mention of 'capital' in this citation, these individuals were far from capitalists. They were artisans brought up in the British tradition. In this respect, they fit the flow of migrant artisans and labourer from Britain to India better than the foreign investment that went into tea, jute, and indigo, in the same time. Migration of European artisans to India had begun in the eighteenth century.[56] Thousands more travelled to India to make a career after the end of the Company's charter in 1813. A substantial number was absorbed in the army, the railways, and the government, but many others joined jobs that demanded skills then unavailable in India, as teachers, lawyers, and artisans. Unfortunately, the precise scale and composition of European migration cannot be measured with certainty. At 1860, the three Presidency towns together had a population of about 15,000 European males of working age, not including Europeans in the army. Only a handful would count as administrative workers, the majority worked in industry and services.[57] Among those employed in the army and the railways were numerous engineers.

The settlers themselves gave rise to a market for 'carriages, furniture of all kinds, palankeens of a peculiar construction, invented by the Europeans, plate, sadlery, boots and shoes, salting meats, in making guns and pistols, and a variety of other articles', which included watch-making, silverware, and glassware. In the eighteenth century, this demand had stimulated the trade in manufactured goods imported from Britain.[58] 'A great number of European artisans .. established themselves in Calcutta, in Patna, at all our cantonments at Lucknow' to produce these goods. Tanneries, glass-works, casting and forging shops and carpentry workshops were established in large numbers. In Calcutta, Madras, and Bombay could be found 'British artisans and manufacturers of almost every description of trade that is exercised in [Britain]: such as coachmakers, carpenters, cabinetmakers, upholsterers, workers in the different metals, workers in all kinds of tanned leather, tailors, and shoemakers'.[59] These members of a European underclass were far removed from the governing elite, and routinely married Indian women. In turn, 'many of the half-cast, or children of European fathers and native mothers are employed in such trades'.[60] In Calcutta, a 'very large shipbuilder' in the 1820s, Kid or Kyd, was of 'half-caste' origin.[61]

Some of these adventurers, including Andrew Duncan and Josiah Marshall Heath, had been iron-masters.

A Scottish iron-master, Andrew Duncan worked for more than 15 years in Scotland and Russia, before arriving in Bengal in 1810.[62] He was engaged by the Company to carry out a survey and prepare a report on the prospects of finding iron in Midnapore and Balasore, and construct a smelting shop and a foundry, on the promise of a sale contract with the Government. His survey took him to Birbhum, where a considerable iron industry then existed, and where he set up an experimental smelting shop. When the landlords discovered that Duncan was not a government employee, they 'left nothing within their power undone to thwart and defeat my purposes'. His workers were bribed or coerced away, and his buildings destroyed. Despite such troubles, he managed to produce some iron in the next seven months.

The Birbhum experiment taught Duncan that the main obstacle to setting up a large-scale workshop was workers. Duncan found it impossible to secure workers willing to learn how to operate the machines that he had brought with himself. The problem inclined him towards a location where European foremen would be more easily available, though Duncan still contemplated employing and training a mainly Indian work-force. Further, he appeared to have dropped the idea of a smelting shop. He was authorised on government expense to erect a foundry on the confluence of the Mayurakshi and Hughly rivers in 1812. In 1814, when the building was completed, Fort William had second thoughts and appointed a committee of engineers to assess the project. The committee's report stated that Duncan was a good ironmaster but a bad accountant, and had underestimated the cost of transporting ore to this spot, Bigpore, and overestimated the cost of importing unwrought and cast iron. Nevertheless, Duncan was asked to start manufacturing. The subsequent history of the enterprise is not clear. The factory possibly manufactured a few shells. But there is no mention of a substantial body of workers being employed here. One of the last pieces of official correspondence on this enterprise sought instructions from Fort William concerning the bullocks procured to transport material. The promise of a historic career having ended, the bullocks spent their last days at the Commissariat slaughterhouse.

The best documented modern venture in smelting was the Porto Novo factory.[63] Porto Novo (Parangipettai) was a one-time port used by Dutch, French and English ships, and a small town located on the north bank of the Vellar river where the river meets the Bay of Bengal. Here, in 1825, Josiah Marshall Heath, a Company servant, sought permission to set up an iron-making factory 'embracing the process of smelting, puddling, and beating out into bars'.[64] Heath's demand was an exclusive lease of ores occurring in the region for the legally maximum time for such lease, 21 years. The grant of an exclusive license drew a threatening response from George Jessop, who had successfully established with his brother a foundry in Calcutta (that lives on today as a state enterprise).[65] On the other hand, Heath received the backing of Thomas Munro, and along with him, a powerful section of Madras administration.

The factory would produce 4000 tons of bar iron, at a cost of £12 per ton. The price of English pig iron was £8.3 per ton at this time. In Heath's license application, the price of bar iron was set at £34-40 per ton in England and £18-24 in India, both figures appear exaggerated. In both markets, Heath managed to convince the concerned Company officers, his enterprise would make profit. The enterprise was troubled from the start. Heath soon found himself in debt to the Calcutta agency house, Alexander and Co., to the extent of Rs. 100,000 for the property purchased in Porto Novo and needed a large loan from the Company to proceed. The Porto Novo Iron Works also raised capital in Madras, by persuading Company surgeons and the Advocate-General in charge of drawing up the contract, to become shareholders. It does not appear that it managed to pay either dividend or interest at any time. By 1840, the company was hopelessly in debt.

As late as 1849, a memorandum by the Accountant General stated that 'the causes of the total failure of the undertaking are at present inexplicable'.[66] While the iron was high priced, lack of demand was not the reason for failure. Although the first batches of pig iron supplied from Porto Novo to England failed to pass the test of quality, the problem was eventually sorted out. ~~In 1859~~ About 1850, Sheffield imported a small quantity of Indian pig iron. In an estimated annual consumption of 35,000-40,000 tons, Indian production, almost all of it from Porto Novo, supplied a quantity slightly less than 1000 tons, a small proportion, but large enough in volume to draw attention. In this market, Porto Novo iron was known for superior quality. Heath's own statement after he returned to England in 1837 complained about the lack of cooperation in Sheffield; about the fact that his goods did not find market in India, and that the Government refused to respond to his call for marketing contract.[67] In Sheffield, however, a different perception prevailed. Heath's problem was not demand, not quality, nor the price, but inelastic scale. Sheffield, in fact, wanted more of Heath's iron, considered unequal for steel tools, but Heath 'indignantly rejected' the offer of a contract to supply a larger and steady volume. 'The fact was, he knew he could not do it.'[68] The problem was on the supply side.

In current scholarship, the explanation of why Porto Novo failed remains conjectural, and therefore, not always persuasive. One work suggests that the enterprise suffered from capital shortage.[69] The interpretation would be convincing, but for the fact that the company was in debt to the tune of nearly a million rupees when it ended. The very prospect of dragging on for twenty years with other peoples' money discounts capital shortage as the critical factor in its demise. In this time, venture capital could be raised, even though the negotiation costs were sometimes quite high, by taking recourse to London, the Company, or Calcutta agency houses. An earlier study surveyed a few other examples of failed European adaptation of indigenous smelting processes, and attributed the failure to incompatibility between indigenous work organization and the scale of the new enterprise.[70] It is true that the two knowledge orders were too far apart and too incompatible to develop working partnerships. However, what we want to know is how this factor made a difference to actual operation of a factory such as Porto Novo. I would argue that the main supply problems in this case were posed by the costs of labour and materials. The reason the government did not support the enterprise as much as Heath had hoped for was the persistent failure to reduce these costs.

A report conducted in 1833 stressed the importance of 'steady intelligent workmen' and steady supply of charcoal to make the enterprise a success.[71] Another report in 1837 was more candid, 'the persons in immediate charge of the machinery at Porto Novo appear to have been not educated men, but merely working artificers.' 'The fundamental defect of there being no competent engineer' contributed to the delayed commissioning of the works. The machines ordered from England were incomplete, operating bellows with cattle power proved ill-conceived, buildings were of insufficient dimension, the European workmen arrived a year after the machinery did, and 'adequate arrangement had not been made for the provision of fuel.'[72] There is no evidence that Porto Novo ever employed Indian workers above the most unskilled tasks. Why did it not employ Indians in supervisory positions? The answer is obvious. Given the character of indigenous smelting in the interior regions, it would be difficult for the owner of a 4000 tons furnace to contemplate making use of smelters practiced to operate two-ton makeshift furnaces.

Transportation of wood fuel was a huge problem in this region that still did not have either good roads or railways. The ores would have to be transported from Salem by rivers and canals, which were navigable for about six months in the year. A small canal used by the factory to transport charcoal dried up.[73] In a further blow to the prospects of the works, the workshop did not have, and despite tortuous negotiations over a decade, failed to establish, undisputed property rights over resources. The Board of Revenue asserted the rights of the people to the common forest lands in the region, including the right to collect wood and ore.[74] The Collector of Salem stated that 'the hundreds of native furnaces at work' in his jurisdiction were already able to provide ‘any quantity of iron required by the people’; that ‘very many make their livelihood by burning charcoal and bringing it for sale to the iron smiths’, and it was his duty to protect these livelihoods.[75] India after all was not a New World colony where the settlers could write their own laws. On the contrary, natural resources such as wood, water, and iron were entangled in complicated customary rights, which some officers of the government felt it their duty to protect.

A yet third contemporary venture on which some information is available is the Kumaon Iron Works, which was formally launched in 1856. It had been officially known for at least thirty years before this date that Kumaon had indigenous smelting, ore, and plenty of wood fuel. In 1856, the Government considered production of charcoal iron with the help of private capital. It appears that two small smelting workshops under government supervision had already been working in this area. Two private agents, Davis and Co. and one Drummond, took over these two workshops. These two firms merged in 1862 to form North of India Kumaon Iron Works Company (Limited). The enterprise had its eyes on potential demand for iron from the railways. But it faced an insurmountable obstacle transporting and accessing wood. Proposal for a light railway to connect the ore region with the nearest major railhead did not materialize until 1864, when the factory was abandoned. Kumaon was rapidly emerging as a major potential source of timber. In the two years of its existence, an elaborate licensing contract was drawn between the company and the Government, which added stringent and in some views impractical clauses on regeneration of forests. The opportunity cost of charcoal, therefore, killed the idea. In 1876, the Government again tried to attract private capital, to no success.[76]

Historians of iron industry have paid particular attention to a series of experiments conducted in Birbhum.[77] In this region, between 1770 and 1870, licenses to mine and/or produce iron in large furnaces were procured, more or less in that order, by one Indranarayan Sharma, Messrs

Mott and Farquhar, several neo-zamindars of whom Baishnabcharan Hajra was the most prominent name, and the Birbhum Iron Works Company set up by Messrs Mackay and Company of Calcutta. The identity of some of these individuals remains obscure. The first of these ventures never began; the second fought exhausting battles with the principal zamindari in Birbhum over rent and with the local smelters over access to material before giving up; Hajra was engaged in a protracted lawsuit with one Madangopal Basu, who had purchased a piece of the now splintered Birbhum raj; and the fourth declined due to competition of cheaper imported iron and increasing cost of transporting wood fuel as forests receded rapidly from the second quarter of the nineteenth century. The correspondence of the Mackay and Company contains the hint that the owners had spent an enormous amount of money hiring workers who, they felt, were dangerously prone to drunkenness. In response to this problem, the company lobbied to ban production of spirit in the neighbourhood of the works.[78]

The examples establish that European enterprise in India failed because of a persistent underestimation of input costs, both measureable direct costs and transaction costs. It faced high energy cost, for wood fuel was costly to transport in regions that did not have many navigable rivers. The European work-force often proved unreliable and inexperienced. Property rights and rights to the commons were not to the advantage of a factory. And given that these works failed to make a convincing attempt to address these problems, the government was only a half-hearted partner in these ventures. Finally, there was a misperception of demand. These enterprises understood the colonial market consisting of the army, public construction, and the railways, and thought a promise to supply these markets would enable them to get concessionary licenses on ore, wood, and market. The colonial market was an unreliable partner, however. Porto Novo made an attempt to sell an iron plough to peasants, but too late and too hesitantly to make any difference to its profitability.[79]

As we move on to the end of the nineteenth century, Indo-European enterprise in iron had begun locating themselves in easy proximity of railway lines that served mining tracts. And they had switched to the reverberatory furnace and coking coal, though some of the early enterprises in coke-furnaces continued to be troubled by the quality of coal.[80] The Tatas issues their prospectus in 1907, having once before abandoned a plan to set up a mill in Chanda. These new proposals contemplated not only much larger scale of operation, but also integration of manufactures, coal washery, labour barracks, township building, and mining, a technological model that had better prospect of succeeding, provided enough capital and marketing support were available.

If the smelting story shows why import substitution was so difficult, the blacksmith story shows how knowledge transactions could facilitate import substitution.

Blacksmiths

The first inkling we have that the blacksmith story may be quite a different one comes from wages data. Between 1870 and 1930, the average earnings of skilled urban artisans including blacksmiths increased about three and a half times, stayed above the average earnings of mill workers, were consistently higher than the wages of rural labourers, and the gap was increasing.[81] It was not the case that business failures were rare among the skilled urban blacksmith, but cases of lost markets were more than matched by new opportunities. There was also more differentiation within the blacksmith community, one end of it being engaged in meeting rural demand and another supplying urban demand. Figure 2 shows the interior of an urban workshop. The latter group especially came in systematic contact with European consumption and imported tools and techniques.

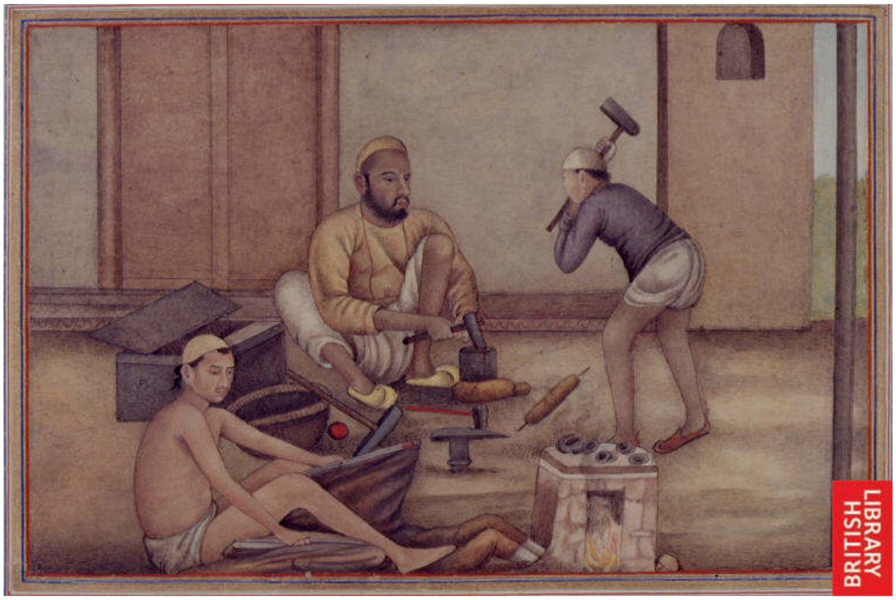

Figure 2. Blacksmith workshop in a north Indian town, 1825

Source: James Skinner, Tashrih al-Aqvam, from British Library images collection.

In this section, I explore one specific ingredient in the improvement in productivity in this sphere, Indo-European collaboration and knowledge spillover. The five major channels of knowledge transfer in which I classify the available evidence are, following a roughly chronological order: early modern coastal trade; European firms in early nineteenth century colonial port cities; military engineers located in the interior of the country; Indian blacksmiths manufacturing small consumption articles for the city market; and technical schools and government factories at the turn of the nineteenth century.

The history of technological transaction in iron goods goes back to the beginning of settlement of European traders on the Indian coast. A description of Indian ship-building on the western coast in the eighteenth century remarked that 'their anchors are mostly European, our iron being much better, and better worked.'[82] There is considerable evidence that, even though casting was not a well-developed indigenous industry, a great deal of ship anchors were being cast in ports using indigenous iron and ironsmiths working under European direction and custom. In the seventeenth century, the Dutch East India Company set up iron works near Palakole on the southwestern coast.[83] The works possibly contained a foundry, employed Indian blacksmiths, and represented a different technological paradigm in shipping, one that employed a great deal more iron than did the Indian ships. Thomas Bowrey, the English merchant who lived in Bengal in the 1670s, observed that the works employed 'Several black Smiths, makeinge all Sorts of iron worke, (necessarie for Ships) whereby they doe Supply most of theire fleets with Such Necessaries'. The 'necessaries' included 'speeks', bolts, and anchors. Apart from iron parts, the cluster also produced rope and twine for the riggings, and had master ship-builders, 'who have most of their dependencies Upon the English, and indeed learnt their art and trade from some of them, by diligently Observinge the ingenuitie of Some that build Ships and Sloops here for the English East India Company and theire Agents..'.[84] Bowrey complained of their 'falseheartedness', at having learnt from the English and yet working for the Dutch. Read in a more positive light, the description hinted at an active labour market for skills. A slightly later source mentioned casting of anchors for ships, though 'not so good as those made in Europe'.[85] These works were located near Balasore, where the English and the Dutch had trading stations before moving up north. One authority on iron considers that the presence of many larger-scale iron smelting workshops in Kathiawad, and near Masulipatnam, were a legacy of the European enterprise connected with ship-building.[86]

After the Company received the *dewanny* of Bengal, Bihar and Orissa, cannons became a major item of import into India. Attempts to substitute imports were sponsored by the importers themselves. A cannon foundry was proposed in 1768 to be erected inside the Fort William, a short time after slightly worried Company officers saw a similar enterprise run by the Nawab of Awadh. Ten years later, a whole blast furnace was contracted, but not delivered, for the use of the Fort William foundry.[87] In the eighteenth century again, Indian princes who had come in close contact with British enterprise and society, the Nawabs of Carnatic and Awadh for example, purchased a great deal of high-bulk prefabricated European iron goods, and sometimes had them made locally. Founding cannons with European help was a popular preoccupation of the regional princes in this time. The Chief Engineer of Fort William, a Col. Polier, who was also an inspiration to James Rennell on cartography, took up employment with the Awadh state.[88] The Carmelite priest Paolino da San Bartolomeo wrote that in the 1770s 'the king of Travancor purchases Every year, from the Europeans, iron, cannon, and cloth for the use of his soldiers'.[89] San Bartolomeo also wrote that there was a garrison of European soldiers in the same place where the arsenal of the Travancore king was located, and made a special note of the 'cannon foundery' that the garrison contained.[90]

Cannons were not the only end-use of a foundry. In the eighteenth century in Calcutta, the afore-mentioned Kyd's docks on Hooghly produced boats that were familiar on the southeastern coast in the early nineteenth century, and further south, a point of anchorage called Gloucester, later Gloster, possessed a ship-building yard that later converted into a cotton factory and a distillery.[91] It can be presumed that both these works contained foundries. James Kyd was an illegitimate son of Robert Kyd (1746-93), engineer in the army, and the founder of the botanical gardens of Calcutta. According to one myth, James was the origin of the name

Kidderpore, where his docks were located. The same site had an even older dockyard belonging to Henry Watson, who became bankrupt. On the opposite shore, in a mud fort a cannon foundry was reportedly in existence in the eighteenth century.[92]

The nineteenth century began with a rapid increase in the import of iron goods into India. The evidence of Charles Atkinson, the Mayor of Sheffield, and Robert Jackson, Master Cutler, recorded before a Parliamentary Committee in 1859 contains general information of the early nineteenth century English exports to India.[93] With the end of the East India Company monopoly trading rights, the scale of business between India and Sheffield grew rapidly. The main articles of export were ‘cutlery, tools of all kinds, more particularly tools for joiners’ and carpenters’ purposes, files and saws, steel, and latterly steel springs for railway purposes .. and hardware generally.’

Interestingly, other than cutlery, many of the products mentioned in this list were tools of trade for the carpenter and the blacksmith. Blacksmiths were sufficiently common among the European population of Calcutta, and more rarely, north India. One of them came in accidental contact with Bishop Heber of Calcutta, on his travels near Allahabad in 1824.[94] The generic carriage workshops of Calcutta saw a joining of European enterprise with Indian skilled labour, both carpenters and blacksmiths. Cutlery had been imported into India in the early-1800s, and yet, a change was visible. ‘I have seen articles of cutlery and even brass instruments made in very considerable perfection; the latter was at the gun carriage yard, in Seringapatam, where European superintendents have instructed some of the half-cast artisans and natives to be very skilful workmen’.[95] The gun-carriage workshop in Madras that provided material for bridges and military purposes was ‘simply a big workshop where all the common tools used by smiths are employed’, and there were several other such workshops in Madras in 1840.[96] Indian workmen worked in considerable numbers in the arsenals, as we have seen, and the Mint at Calcutta, where their skill in cutting the dies, turning lathe, and rolling copper into sheets ‘with equal facility as if performed by the best European workmen’ impressed David Smith, the Government Iron and Coal Viewer, in 1856. Smith also felt that without a change of food and dress, the weakly built ‘Bengalee’ would not be able to stand the heat and the hard work of the puddling or the rolling mills of average scale then usual in Britain.[97]

A travelogue published in 1837 contains a detailed description of Monghyr in Bihar, the erstwhile capital of Bengal, where a large number of manufactories produced a great variety of durable goods. The concept of many of these goods had come from Europe, but the manufacturing process and the skills derived from indigenous workmanship.[98] Some of these goods met new consumption and were manufactured ‘under the inspection of persons well ancquanited with these arts’. The most famous branch of such hybrid enterprise consisted of arms.Foremost among ‘the vast number of new articles’ found in Monghyr in the 1830s were double-barelled guns and rifles. The ‘blacksmiths, who work up steel and iron into a great variety of forms’ hailed from an indigenous tradition already making ‘the best kind .. of spears’. But their workmanship was easily adaptable, and they promised to be ‘easily trained .. in any mechanical employment.’ This source on Monghyr expressly mentioned the absence of European owned workshop in the town, even though the buyers of these goods, who included many Europeans, sometimes ntervened in the design of the goods. This pattern did not change radically in the ninteenth century. Blacksmiths continued to be predominantly Indians. But a few significant exceptions can be found.

A somewhat well-recorded Indo-European enterprise was the firm of James Petrie, a cotton ginner in Coimbatore. His experience points at a few general features of skill transfer in machine-using industries.[99] Manufacturing had become more complex and more mechanized between 1814 and 1847, and by the latter date, some manufacturers needed to hire local hands to fabricate and repair machinery. Usually, carpenters and blacksmiths performed such tasks. Learning did not pose any obstacle. 'In a very short time, almost an incredibly short time, they learnt to make up the machines which I required.' But learning also occurred on the blacksmiths' own terms. There was no wholesale substitution of English practice for Indian practice; rather, Indian artisans combined old and new tools, traditional and new modes of working. Indian carpenters typically worked with few metal tools, a chisel, a plane, and an axe at the most, all of which they used flexibly for a variety of purposes. Blacksmiths worked individually with small bellows and hammers, often setting themselves up under the shade of a tree, sitting down unlike the European forge-shop workers who worked standing up. 'These modes of working did not answer my purpose'. Petrie imported large bellows, anvils, vices, and turning lathes from the ordnance factory at Madras. When set to work 'in European fashion', the blacksmiths surprised him. They rearranged the tools to be able to sit down and work them, and dispensed with the vice which the Indian blacksmith rarely used. Whenever Petrie paid visits to the work-space, they stood up to reassure him. After a few such occasions, Petrie did not press the issue. Either way, they produced work of a sufficient quality for the owner to declare, 'I think they are as easily learnt as a similar class of men in England would be that had never seen such work before.'[100]

Military campaigns had placed contingents of soldiers in territories that did not have good roads and bridges. In two examples from the second third of the nineteenth century, both occurring in a region rich in iron ore and yet distant from the port cities where skilled labourers were available, we see an attempt by military engineers to recruit local artisans for a large scale construction work. Before Nagpur became the intersection point of the north-south and east-west transportation routes, Jubbulpore held that position of importance. Goods and people from the Hyderabad region traveled north via Chhindwara, Narsinghpur, and Jubbulpore en route to Sagar. On this route, a stream that became impassable in the monsoons was forded by an iron suspension bridge c. 1830 by one Colonel Pesgrave posted in this territory.[101] There was no European settlement and few foremen in Pesgrave's team. It is not known if any member of the team possessed direct knowledge of either bridge-building or iron-making. Nevertheless, they gathered together a number of blacksmiths and smelters from the countryside. Such people were drawn by word of mouth, curiosity, and a prospect of wage work. Bit by bit, the links were constructed, put together, carried over the river and put in place. In Punasa jail in Nimar, again in central India, Lieutenant R.H. Keatinge installed an indigenous process of iron manufacture shortly before the Mutiny, with the help of jail labour. The works contained a heavy tilt hammer to refine the crude iron. He was about to set up a rolling mill when the Mutiny broke out and he was called away.[102]

Reports of such Indo-European enterprises begin to become scarcer after 1857. A different kind of relocation of skill begins to draw more attention thereafter, a shift of capital and enterprise away from the country blacksmith tied to the smelting communities, towards urban smithy and town markets. Whereas the former world remained trapped in nearly stagnant consumption, the urban world saw significant growth in the market for cutlery, industrial tools, railway rolling stock, bridge-building, and arsenal. An 1830s description from Bihar observed the division between the country blacksmith and the blacksmiths of Patna or Munger.[103] The former were blacksmiths engaged in producing agricultural implements, who 'usually belong to the manorial establishment, and the payments for the implements of agriculture arises from a share of the crop.' The latter were more specialized in iron, and manufactured a variety of goods, ‘vessels for boiling sugar and sweetmeats, the drums called *nakarah*, nails, locks and chest hinges, and more rarely bird cages and horseshoes’. Their earnings were double the average that obtained in the village. Imported goods and domestic production supplied that market jointly, with the latter’s share possibly increasing. In Bundelkhand likewise, village blacksmiths joined the urban foundries and forges. They had to be retrained, for they needed to know the ways of handling coal furnaces that worked on higher temperatures. They had to be trained on ‘accuracy’ and working to customized dimensions. These were matters of importance when the blacksmith supplied machine parts rather than agricultural tools.[104]

In the Narmada valley in central India, ‘when iron came to be imported on a large scale, the wealthier Lohars found that it suited them to make use of the foreign material, which, though it might be more expensive, was in a more convenient form. .. They thus naturally drifted to the larger towns, where the imported material was more readily obtainable and the field of custom wider.’[105] Imported bar iron was at first preferred for the convenient shape rather than the low cost, but increasingly also preferred for the cost. By 1900, in towns located in prosperous agricultural tracts (such as Hoshangabad), the urban blacksmith belonged in ‘a substantial and prosperous class’.[106] A slightly different case of skill development through making new goods using new materials occurred in the sphere of production of matchlocks in Bihar. In Monghyr in the mid-Gangetic plains and in Dhampur and Nagina in the Himalayan foothills, matchlocks were made with or without official sanction in the mid-nineteenth century, as we have seen. ‘The ability of the clever lohars is strikingly shown in their power of copying good European firearms of the modern type.’[107] This industry often employed designers, polishers, and wire-drawers to decorate the barrels of the guns or other parts.

A larger field of import substitution occurred in cutlery. With the coming of imported English and Swedish iron, a new urban demand for cutlery grew rapidly. At the start of the nineteenth century, articles of steel in ordinary use, including cutlery, knives and scissors, 'are generally imported from England, being very superior to those manufactured in India'.[108] By 1900, however, cutlery manufacture occurred in nearly all larger cities, or within clusters with easy access to transportation. Blacksmiths engaged in meeting the new demand required a higher degree of skill in the shape of product differentiation than was necessary with agricultural implements. It is in this sphere that master artisans could be found. 'This higher class of work is carried out in larger shops and the workers are the employés of the master cutler'. Skill commanded a wage premium. The average monthly income of Rs. 15 at 1900 placed the cutler at the top of the urban wage scale.[109] Prem Chand Mistry was the owner of a workshop in Kanchannagar, a small locality in the Burdwan district of western Bengal that had developed as a concentration of the manufacture of iron tools, implements, and cutlery since at least the nineteenth century. A government report of 1890 mentioned Mistry's workshop for having successfully introduced a hand-driven lathe.[110] Twenty years later, in another report on Bengal manufactures, 'the well-known shop' of Prem Chand Mistry finds mention again, for having introduced oil-engine to drive his lathes.[111] In both instances, his technological leadership was seen as a model for small-scale metal products industry in general.

At the turn of the century, the labour market opened up to admit non-family apprentices. 'In a typical shop' making cutlery in the towns of Eastern India, 'the following men were found at work: two owners, superintending, finishing and packing, etc.: two men at the forge, and a boy to work the bellows: one boy for filing the handles: three men for hammering and filing the blades: one man for joining the two portions together'[112] Such workshops could not follow the practice common in the villages of securing labour by means of intra-community cooperation. In Bundelkhand towns, there was a shortage of workers, and hereditary knowledge was not necessarily an advantage. Employers complained of shortage of skilled mechanics, the best being drawn away to Calcutta or other larger cities. In industrial towns, therefore, smithy recruited raw workers from different caste backgrounds, and a more or less formal system of apprenticeship was practiced.[113] In the Narmada valley again, we observe greater utilization of non-family, if intra-community, apprentices.[114] Business organization opened up too. Larger workshops and partnerships were usual in the cities. It was this state of activity in the labour market that explained the rise in blacksmith wages discussed earlier.

The cities also saw a completely new factory industry develop from the end of the nineteenth century, operating on European pattern with blast furnaces, foundry shops, rolling mills, and mechanical forges. The railway construction created an immense new demand for rolling stock, rails, sleepers, wires, bars, and rods. This demand encouraged private entrepreneurs to start iron-making using coke and rolling mills in Bengal, shortly after P.N. Bose's reports on the deposits of the essential raw material in the Bengal-Bihar area became well-known. In the rolling mills of Calcutta, all designs and equipment were imported, and so were the foremen. The ordnance factory of Calcutta had large metal-working shops, and recruited thousands of workers. Public works and urban construction provided impetus to the factory industry.

An important new field of training was the railway workshops that employed both blacksmiths and carpenters in large numbers, often on job-work basis. In Bombay in the early twentieth century, 'Lohars from Gujarat were preponderant among the smiths in the wheel shop', whereas the foremen were all Europeans.[115] The Roorkee engineering college, established in 1848 and later renamed after James Thomason who had facilitated the new Grand Trunk Road and the Ganges canal, had a foundry, 'the first of the kind erected in India'. The foundry was erected before demand for iron from the railways took off, though the resources of the college were closely associated with the construction of the Ganges canal. In its origins, the foundry could not have employed local workers. But by 1873, not only were the workmen all Indians, 'they will make anything for anybody, from an iron bridge or a steam engine, down to a railway key; and they turn out excellent spirit levels, prismatic compasses, and so forth'.[116]

The principal gun factory of British India, located in Calcutta, reported that 'the labour as recruited is generally quite untrained'. A large proportion was migrant Muslims, whereas among the Bengali blacksmiths, Muslims had been conspicuously rare. The factory created its own system of training workers, and reported a large skill and wage differential between the ordinary tool-shop worker and the mechanic.[117] Such differentials reflected the opportunity cost of the mechanic, who left 'frequently .. to find employment with private firms'. In other words, a hierarchy between the literate class of foremen with formal training, and the raw workers, had formed. The situation inside the cotton textile mills of Bombay, where a hierarchy between the Parsi or the European supervisors and the workers was in existence, was similar.[118]

In these new enterprises and organizations, the world of the formally trained Indian engineer, and that of the informally trained Indian blacksmith were coming into increasing contact. Civil engineering was introduced as a university subject in the 1870s, and drew a sizeable number of Indians about 1900. The students in the university degree programmes in engineering numbered only a few dozen in 1900 and all hailed from 'the babu class'; that is, the gentry rather than the working people. The 'babu' graduates usually joined the Public Works Department. These programmes had an externality. The civil engineering schools had mechanical shops affiliated to them, which recruited men of artisanal class as apprentice-cumworkers. There were also, at 1900, about half a dozen provincial technical schools in Bengal attached to the Calcutta University. These schools offered short courses in machining. In this way boys of 'the mistry class' received formal training, and their number was growing.

Conclusion

The iron industry in nineteenth century India was transformed by the availability of imported goods, tools, and skills. What was the nature of the transformation? Did colonialism and globalization aid or obstruct industrial development? According to the received view, the outcome was a negative one, for imported goods destroyed indigenous industry, and the colonial state distorted and obstructed wide utilization of imported tools and skills. In this paper, I argue that factor costs, as distinct from political variables, explain the link between technological exchange and industrial development better. The outcome of globalization was not uniform, but a mixed one, because factor costs were sometimes significantly large, and sometimes relatively low.

To illustrate this proposition, the paper compares the experiences of smelting and smithy. Artisan communities producing semi-finished iron tended to be located near the ores and worked on a scale and level of capability adapted to meeting local rural demand for iron. Production costs were relatively high, but the industry was protected by high transport cost. Transport costs limited trade, average scale of production, and interregional knowledge exchange. In the second half of the nineteenth century, indigenous smelting entered a crisis. The railways reduced transportation costs, and brought markets within easy access of cheaper imported goods. Wood fuel began to become scarce, as forests were reserved, alternative demands for wood in construction, ship-building and railways grew, and in some regions, woods ran out. Given its dependence on rural markets, artisanal smelting could not possibly expand scale, economize, and absorb these costs. European artisans in India tried the larger-scale and horizontally integrated factory. The physical distance between their targeted market, which was the government, and the origin of ores again posed a transport cost problem. The one hypothetical advantage they had in conducting enterprises in India was cheap labour. But Indian labour was located near the ores, usually found working within traditional institutions such as the household, and used to operating small-scale units. There was an almost unbridgeable distance between Indian labour and European capital. On the other hand, skilled labour imported from Britain did not necessarily provide a solution. They were often unreliable and inefficient, suggesting that migration of wage-workers from Britain to India in this time suffered from an adverse selection problem. And in common with indigenous smelting, European smelting had to contend with the rising scarcity of wood fuel.

In contrast with the smelters, many of the specialist blacksmiths belonged in urban communities, were more familiar with contractual service for a diverse range of clients, closer to consumer markets rather than ore supplies, and therefore less susceptible to the adverse effects of narrow markets. In this sphere, globalization had a more adaptive effect. The only complementary factor necessary to make good use of imported tools and ideas was craftsmanship, already available in abundance. Retraining needs were not always great and retraining prospects better in the towns. Much knowledge was embodied in small tools, which had been partly imported, and partly substituted with refashioned local tools. There were small economies of scale in smithy; consequently capital cost was of little consequence. The city, the ports, the barracks, and the public works, allowed a convergence of knowledge to develop between European and Indian artisans. Blacksmiths benefited from the unconventional communication opportunities provided by these new sites, while adapting new knowledge in their own way. European money was present in this sphere, but it was not an essential factor; the learning process was led by the urban Indian blacksmith.

The present study of iron, in contrast with previous ones, stresses some of the costs of starting large-scale resource-intensive industries in mid-nineteenth century India. Could more aggressive state intervention reduce these costs? The role of the state in the early nineteenth century was evidently minimal, among other reasons because many actors within the state machine understood the barriers that private capitalists needed to overcome. A new iron factory in 1840 would need to build railways and canals, enter protracted negotiations on mining or land acquisition at a time when property rights had been redefined and allocated, wait indefinitely for machines to arrive and then have them faultily assembled by inebriated poorly trained European foremen, and depend on European markets. In the presence of high costs of so many complementary inputs, it could not have been easy for a state to play the infant industry game. By contrast, in the second half of the nineteenth century, the prospect of effective state intervention brightened as the costs of accessing machines, material, and manpower declined. Increasingly, the only remaining barrier to the success of large-scale enterprise was cost of capital. In this scenario, direct market assistance could realistically work, and it did work for the Tatas.

Finally, the iron example carries a lesson on the differential prospects that migrant artisans, the channel of knowledge transfer stressed in this paper, faced in different regions of the world. The scale of settler migration to India was small compared with that of the colonies of the north Atlantic. And the scale of net migration (net of emigration from India) slowed after Crown rule began. As wage-gap between Britain and India widened, and New World migration became a flood, newcomers to India needed to be paid a higher wage than their predecessors a century ago could hope to get. Such expected wages restricted recruitment of technical people to a small segment in the formal sector.[119] But it would be a mistake to compare the two migrations only on scale. They differed in qualitative terms. In the north Atlantic, skills were exported as they were found in points of origin. India had an established artisan tradition, and plentiful indigenous commercial and industrial skills, before colonization. Settlers needed to come to terms with this resource. Success and failure of foreign enterprise in early-colonial India depended on how well or badly the grounds for such collaboration could be created.

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Notes

[1] I use 'globalization' in two senses – an historical process of rapidly increasing international transactions in commodity, labour, and capital that characterized the nineteenth century world, and a label that represents theoretical models developed to understand the effect of international economic integration upon world inequality. Colonialism in South Asia was an influential driver of market integration.

[2] The best-known statement owes to Bagchi, 'De-industrialisation in India', and 'De-industrialisation in Gangetic Bihar'.

[3] The link between destruction of industry and world inequality figure in development and trade scholarship as well. One of the enduring links is the notion that manufacturing permits increasing returns to scale whereas agriculture leads to diminishing returns. A second link is the idea that agriculture is a weak engine of growth due to Engel's law and terms-of-trade shocks. A third considers job-loss for skilled labour. See Clark, *Conditions of Economic Progress*; Krugman and Venables, 'Globalization and Inequality'; Wood and Ridao-Cano, 'Skill, Trade, and International Inequality'. For stylized models of the historical roots of Indian poverty making use of de-industrialization, see Dutt, 'Origins' and Eswaran and Kotwal, *Why Poverty Persists*. An earlier influential contribution is Hymer and Resnick, 'Model of an Agrarian Economy'.

[4] Headrick, *Tentacles of Progress*, p. 10. See also for interpretations in this vein, Baber, *Science of Empire*; Inkster, 'Colonial and Neo-Colonial Transfers'.

[5] Inkster, 'Colonial and Neo-Colonial Transfers', p. 42; and Inkster, 'Science, Technology and Imperialism'.

[6] Three of the four principal segments of the industry – artisans, foreign enterprise in smelting, and manufacture of pig iron by the Bessemer process – have received attention. See Bhattacharya, 'Iron

Smelters', Biswas, 'Iron and Steel', Roy, 'Knowledge and Divergence', Rungta, *Rise of Business Corporations*, Headrick, *Tentacles of Progress,* on the first two spheres of enterprise; and Bagchi, *Private Investment*, Ray, *Industrialization*, and Morris, 'Growth of Large-scale Industry', on the third. Partahsarathi, 'Iron-smelting' contains an overview of both traditional and modern enterprise in the nineteenth century. The fourth segment, blacksmiths, has not been the subject of a detailed historical study yet.

[7] On the centrality of colonial political attitudes as a factor behind the delayed start of a modern iron and steel industry in India, see Headrick, *Tentacles of Progress*, pp. 295-6. On the point of loss of knowledge, see Parthasarathi, 'Iron-smelting'.

[8] Some of the most important tools and processes adopted by the weavers in late-colonial India, such as the fly-shuttle sley, the frame-mounted loom, the jacquard, dobby, drop-box, and synthetic dyes, had been invented in Europe between the late eighteenth and the late nineteenth centuries. Roy, *Traditional Industry*, and 'Acceptance of Innovations', contain a statement and some illustrations.

[9] Krugman, 'Scale Economies'.

[10] Grossman and Helpman, 'Trade, Innovation, and Growth'.

[11] The historical literature on large-scale technological transformation also deals with motivations for choice, the diffusion dynamic, and the contents of a package that get chosen. On factor costs as motivation, see Ruttan and Hayami, 'Technology Transfer'. The particular role of communication networks and urban clusters in knowledge transfer is explored in another literature, see, for example, Nelson, 'Less Developed Countries', Wright, 'Can a Nation Learn?'

[12] Epstein, 'Craft Guilds', and 'Property Rights'. Artisan migration as an adjunct to state formation and state decay in early modern India is studied in Haynes and Roy, 'Conceiving Mobility'. Artisan migration was important before the Industrial Revolution because machines themselves were simple

in construction, foreign investment was insignificant, and artisanal knowledge was embodied in the experience and conventions of skilled masters. Within Western Europe, organized attempts to copy and steal ideas were also present in the eighteenth century, when practical knowledge became one front among many along which the political and military rivalry among states was conducted, see Harris, *Industrial Espionage*.

[13] The impact of such transfer is linked with both domestic capacity to absorb, and imperfections in the market for knowledge. On discussions of the relevant literature, and pessimistic as well as optimistic case studies, see Teece, 'The Market for Know-How'; Mohanan Pillai and Subrahmanian, 'Rhetoric and Reality'; Kojima, *Direct Foreign Investment*; Stiglitz, 'Some Lessons'. A branch of comparative management explores cultural variables that impinge on capacity to absorb foreign technology, Kedia and Bhagat, 'Cultural Constraints'.

[14] Headrick, *Tentacles of Progress*; Inkster, 'Colonial and Neo-colonial Transfers'; and Baber, *Science of Empire*; on the railways; Tann and Aitken, 'Diffusion of the Stationary Steam Engine'; Ambirajan, 'Science and Technology Education'; Kumar, 'Colonial Requirements', Ghose, 'Commercial Needs'. See also several essays and the introduction in MacLeod and Kumar, eds., *Technology and the Raj*.

[15] Inkster, 'Colonial and Neo-Colonial Transfers'.

[16] Derbyshire, 'The Building of India's Railways'.

[17] See Tripathi, 'Colonialism and Technology Choices', for a discussion of this view.

[18] Between the first origins of cotton mills in Bombay, and 1925, the percentage of Europeans among the supervisory staff decreased from 100 per cent to less than 30 per cent. See Morris, 'Recruitment'.

[19] Tripathi, 'Colonialism and Technology Choices'.

[20] The major published sources on the economic side of the industry between 1800 and 1865 are Buchanan, *Journey*, Heyne, *Tracts*, and Percy, *Metallurgy*.

[21] Hammersley, 'The Charcoal Iron Industry'.

[22] Biswas, 'Iron and Steel'. Buchanan contains descriptions of ironworks in many places in Mysore and Malabar, *Journey*. The Mysore descriptions have a repetitive quality. In the majority of the works, a team of 10-15 workers operated smelting shops, the team sometimes included charcoal makers and forge operators. The net output, which consisted of agricultural tools, was shared between the members. There is frequent mention of a headman or a skilled artisan who received the largest part. The person was usually the one in charge of erecting the furnace.

[23] Estimated by Thomas Oldham in 1852, reported in Gupta, *Rarher Samaj*, p. 263.

[24] Buchanan reported that in a larger work in Mysore, one furnace was capable of producing bar iron of 11 lbs. per day, or 1.6-1.9 tons per year. At a time, three furnaces were at work, which employed 22 workers in all. The majority of these workers were part-timers, *Journey*, pp. 16-7. In 1906, six small iron mines in Garhwal produced 3.5 tons of pig iron, Dobbs, *Monograph*, p. 11; About 1900 in central India, the output of 200-250 semi-permanent furnaces was estimated at 400 tons of refined iron. The average annual output of a furnace did not exceed 2.4 to 3 tons of crude iron, Begbie, *Monograph*, p. 32.

[25] Gupta, *Rarher Samaj*, p.253. According to this work, one charge took seven days, and produced 20 maunds of iron with 100 workers.

[26] Roy, 'Knowledge and Divergence'.

[27] The number is equivalent to a team of five members erecting a makeshift furnace ten times a year. These are reasonable parameters to assume for the semi-nomadic iron smelting industry.

[28] Biswas, 'Iron and Steel'.

[29] The maximum distance reportedly covered was about 180 miles to the north, the location of Monghyr town. From Monghyr, traders came to Birbhum to purchase raw material for the town's famous gun-making industry, Gupta, *Rarher Samaj*, p. 262. An 1852 exploration of the Kharagpur hills south of Monghyr discovered that in this inaccessible region, 'a tolerable quantity of iron is smelted.., generally in the jungle for the sake of being near the spot where the charcoal is burned.' The smelters operate 'the rudest of furnaces and exchange the metal with the lowlanders for salt, tobacco, or rice.' Sherwill, 'Kurrukpore Hills'.

[30] Watson, 'Chirra Punji'.

[31] I base this proposition on plausible conjectures about the size of armies, the average weight of steel carried per person, and a stock-flow ratio.

[32] Pearson, 'Experiments and Observations'; Mushet, 'Experiments on Wootz'; and the influential study by Stodart and Faraday, 'On the Alloys of Steel'.

[33] Balfour, 'Migratory Tribes'.

[34] They would take the blooms, 'move about from village to village with an anvil, a hammer and tongs, and building a small furnace under a tree, make and repair iron implements for the villagers', Russell and Hira Lal, *Tribes and* castes, p. 10. A later anthropological study of the Agarias has attained the status of a classic, Elwin, *The Agaria*.

[35] In Bundelkhand, the smelters were also Lohars or smiths by caste. Dobbs, *Monograph*, p. 13.

[36] The *reti*, or the file, 'is often the only tool he has not made himself', *Ibid.*, p. 3.

[37] At the end of the nineteenth century in Bundelkhand could be found a nomadic community of blacksmiths, who 'at certain seasons migrate from Rajputana .. wander about from place to place with their families, goods, and chattels', and forged ploughshares for a fee. According to community lore, they had left Chittore when that city fell to the Mughals, vowing never to return until Chittore

was liberated with the swords that they would themselves make and sell to the prospective liberators. Dobbs, *Monograph*, p. 5.

[38] Medley, *India and Indian Engineering*, p. 59.

[39] Dobbs, *Monograph*, p. 8.

[40] *Ibid.*, p. 4.

[41] Begbie, *Monograph*, pp. 4-5, 17.

[42] *Ibid.*, p. 28.

[43] Dobbs, *Monograph,* p. 11; Begbie, Monograph, p. 26; Allen, 'International Competition'; Scudamore, *Monograph*, p. 6.

[44] Roy, 'Knowledge and Divergence'.

[45] Ball, *Jungle Life*, p. 669.

[46] *Ibid.*

[47] Beckett, 'Iron and Copper Mines'.

[48] Dobbs, *Monograph*, p. 12.

[49] Hegde, 'Model for Understanding'.

[50] Begbie, *Monograph*, p. 26.

[51] Gupta, *Rarher Samaj*, p. 253; Beckett, 'Iron and Copper Mines'.

[52] Bhattacharya, 'Iron Smelting', and Gupta, *Rarher Samaj*, emphasize this factor in their accounts of the decline of artisanal iron.

[53] *Narrative of a Journey*, p. 482.

[54] *Ibid.*, p. 52.

[55] B.P.P., 1859 Session 1 (198), *Select Committee*, pp. 245-250.

[56] Among the more colourful early figures was the legendary Samroo or Walter Reinhard. Before he found his vocation as the commander of mercenary forces, Samroo had been a skilled carpenter who came to India possibly with the French East India Company. Other prominent migrants of artisan background who established a reputation in other walks of life included William Carey, shoemaker by family occupation, and David Hare, watch-maker.

[57] India, *Statistical Abstract*. For some references to the early nineteenth century European migration and the professions that received them, see Hawes, *Poor Relations*, p. v.

[58] *Interesting Extracts*, evidence of Alexander Kyd, p. 4. The recent work of Huw Bowen contributes to this theme, 'Consumption of British Manufactured Goods in India'.

[59] *Interesting Extracts*, evidence of John Malcolm, p. 3.

[60] *Ibid*., p. 3.

[61] House of Lords, *Report from the Select Committee*, p. 45.

[62] India Office Records, IOR/F/4/489/11862.

[63] Morris, 'Large-scale industry'; Rungta, The Rise of business corporations; Parthasarathi, 'Iron-smelting', contain important descriptions. None offers an adequate explanation of the failure of the enterprise.

[64] B.P.P. 1852-53 (634), *Despatches, Minutes and Reports*, p. 3.

[65] *Ibid*., p. 123.

[66] *Ibid*., p. 467.

[67] *Ibid*., pp. 32-5, 259.

[68] J. Ochterlony, Engineer on J.M. Heath's enterprise, B.P.P. 1857-58 (415) Select Committee, p. 17.

[69] Parthasarathi, 'Iron-smelting'.

[70] Bhattacharya, 'Cultural and Social Constraints'.

[71] *Ibid.*, p. 161.

[72] *Ibid.*, pp. 266-7.

[73] *Ibid.*, p. 434.

[74] *Ibid.*, p. 325.

[75] *Ibid.*, p. 339.

[76] Dobbs, *Monograph*, pp. 9-10.

[77] Sanyal, 'Indigenous Iron'; Bhattacharya, 'Iron Smelting'; Gupta, *Rarher Samaj*, pp. 251-84; Majumdar, *Birbhum*, pp. 117-123.

[78] Gupta, *Rarher Samaj*, p. 283. The company started operation in 1855 and ended about 1870. Their works in Mohammadbazar and Deucha also employed unemployed local artisans, *Ibid.*, pp. 265-6.

[79] More on the plough venture, see Bhattacharya, 'Cultural and Social Constraints'.

[80] India Office Records, IOR/V/27/612/9, pp. 3-4, 12-15, 38-40. Bengal Iron Works, one of the first enterprises using coke, set up two small blast furnaces each with the capacity of 20 tons of pig iron per day. The factory closed down in 1879, when its cost of production proved about 12-15 per cent above the market price of English cast iron goods in Calcutta. The report by von Schwarz identified several design problems with the works, but more critically, the inability to handle the high ash Bengal coal. The Nurbudda Coal and Iron Company was established with a capital of £250,000, in 1860, but never started operation. In 1875, a mining engineer of the name Ness, based in Warora, tried to experimentally smelt iron with Chanda coal. He ran up a temperature that melted the fire bricks, but failed to melt the iron ore.

[81] Atkinson, 'Statistical review'; Sivasubramonian, *National Income*.

[82] Grose, *Voyage*, p. 109.

[83] Subrahmanyam, 'Note of Narsapur Peta'.

[84] Bowrey, *Geographical Account*, p. 102-5.

[85] Hamilton, 'A New Account', p. 392.

[86] Biswas, 'Iron and Steel'.

[87] *Fort William-India House Correspondence*, Vol. V, p. 156; vol. VII, pp. 43, 297.

[88] LaTouche, *Journals of Major James Rennell*, p. 110.

[89] *Voyage to the East Indies*, p. 166.

[90] *Ibid.*, p. 113.

[91] Holman, *Travels in Madras, Ceylon, Mauritius*, pp. 448, 452.

[92] Yule, ed., *The Diary of William Hedges*, p. ccxv.

[93] B.P.P. 1859 Session 1 (198), *Select Committee*, pp. 245-250.

[94] Heber needed to shoe a horse. Unable to contact the town blacksmiths, the party had the good fortune to receive a visit from 'an elderly European in a shabby gig'. He turned out to be a blacksmith from Lancashire, a 'farrier many years to a dragoon regiment, and .. now a pensioner, on his way to Allahabad in search of employment in his trade.' His samples were good enough for Heber to engage him to replace a number of horse-shoes, upon which he left with a strong reference letter. *Narrative of a Journey*, p. 353.

[95] *Interesting Extracts*, evidence of John Malcolm, p. 4.

[96] B.P.P. 1852-53 (634), *Despatches, Minutes and Reports*, evidence of Captain J. Campbell, p. 384.

[97] India Office Records, IOR/V/27/610/15.

[98] Roberts, *Scenes and characteristics of Hindostan*, vol. 1, pp. 296-8

[99] B.P.P. 1847-48 (511), *Select Committee on Growth of Cotton*, pp. 178-9.

[100] The posture of the workmen posed a similar problem with carpenters working in the railway workshop of Lahore, Medley, *India and Indian Engineering*, p. 59.

[101] This person was possibly the same Col. D. Pesgrave who contributed an article in the proceedings of the Asiatic Society of Bengal (in 1835) on how to protect the piano forte from the adverse effects of Indian climate by fitting an iron rod to the frame.

[102] India Office Records, IOR/V/27/612/9.

[103] Martin, *History, Antiquities, Topography, and Statistics of Eastern India*, p. 343.

[104] Dobbs, *Monograph*, pp. 4-5.

[105] Begbie, *Monograph*, pp. 4-5.

[106] *Ibid.*, p. 58

[107] Dobbs, *Monograph*, p. 18.

[108] B.P.P. 1812-13 (122), *Select Committee*, evidence of Thomas Sydenham, p. 365.

[109] Watson, *Monograph*, p. 33.

[110] Quoted by Mukharji, *Monograph*, p. 27.

[111] Gupta, *Survey of Resources*, p. 48.

[112] Dobbs, *Monograph,* p. 23.

[113] 'Boys are employed on the simpler work at a couple of rupees a month, and their pay is gradually increased according to their proficiency. In factories, children under 14 are admitted only with their parents, yet, apart from these, there are often found very useful workmen "trained on the premises".' There was, nevertheless, a tension between family-based learning and non-family apprenticeship. 'Outsiders sometimes learn at a disadvantage, for workmen are unwilling to teach the best results of their experience except to their own sons.' Dobbs, *Monograph*, p. 106.

[114] Their [the Lohars'] sons went to school, while also working as an apprentice in the father's forge or the shop of another Lohar, where they were not paid any wage and they did not pay a fee. By the age of 15 they began to work on their own account. Begbie, *Monograph*, p. 58

[115] Chandavarkar, *Origins*, p. 225.

[116] Medley, *India and Indian Engineering*, pp. 42-3.

[117] *Ibid.*, p. 48.

[118] The hierarchy inside rolling mills was influenced partly by differences in expected daily output of different categories of workers. Ritter von Schwarz's description of a rolling mill in Bengal compares the situation in England and America, where the average output of a single-rails rolling mill could go up to 440 tons a day, 600 tons not being unknown, with that in Bengal, where the prevailing 'manual aptitude and practice' made a yield beyond 200 tons unrealistic. India Office Records, IOR/V/27/612/9, pp. 12-3. It is not altogether clear whether the difference resulted from quality of training or the length of the working day.

[119] Further, as Britain's own industrial lead began to slacken, India could potentially source knowledge and experts from other Atlantic regions, even Japan. The interwar period saw evidence of this diversification.