BORROWED TECHNOLOGY IN THE IRON
AND STEEL INDUSTRY: A COMPARISON
BETWEEN BRAZIL, INDIA AND JAPAN*

By AKIRA ONO*

I. Purpose of the Study and a Short Summary of Findings

Borrowed technology very often signifies the adoption of advanced methods of production without modification. It is true that technology transfer enables LDCs to attain a higher rate of economic growth, but the importation of capital-intensive methods without modification, i.e., non-adapted borrowed technology, tends to lower labor's relative share, and also to restrict employment opportunity in the modern sector of the LDC economy.

The raw silk industry in prewar Japan provides an outstanding example of adapted borrowed technology, in which imported machines were modified by exchanging iron frames for wooden ones, or by using water power instead of steam one. By so doing, reeling equipment became less capital-intensive, being adapted to the domestic factor price ratios. The adaptation of borrowed technology excludes its unfavorable effects upon labor's relative share and employment opportunity, and promotes through learning-by-doing the technological ability necessary to economic development.

The first objective of this paper is to ascertain whether the adaptation of borrowed technology is a more general pattern of behavior of Japanese entrepreneurs which can be observed in other industries than the raw silk industry. For this purpose, I have selected the iron and steel industry in prewar Japan. The major findings for Japan are: (1) technology adaptation was made by a private ironworks in the early Meiji period, (2) but in the subsequent years there was a shift from adapted to non-adapted borrowed technology, and (3) this shift occurred together with a change from scaled down to scaled up equipment. Scaling down of equipment at the early stage of technology transplantation was for the purpose of acquiring the technical, organizational and operational characteristics that were specific to the modern technology.

The second objective is to examine whether a similarity can be found between Japanese and LDC experiences. For the purpose of comparison, Brazil and India were chosen mainly because of the availability of information. Non-adapted importation was a prevailing

* Professor (Kyoju) of Labor Economics.
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1 A. Gerschenkron (7).
2 A. Ono (21).
form of technology transfer in case of steel mills newly established with the assistance of advanced countries. However, two points should be mentioned. (1) Charcoal-fed blast furnaces still existing in Brazil may safely be considered as technology adaptation. Since charcoal restricts the size of the furnace, producers of charcoal-made pigs cannot enjoy scale economy to a full extent. Blending charcoal with coke or erecting coke-operated furnaces is, to my mind, the attempts at realizing scale economy. (2) Scaling down of equipment can be found in Brazil and India in the postwar period. USIMINAS is a fine example which showed a similarity with the Japanese experience in that the size of equipment increased rapidly after a short period of scaling down.

The third objective is to discuss why LDCs are apt to adopt capital-intensive methods of production. This refers to the factor proportions problem. Several factors are examined, such as technological fixity, availability of capital markets abroad, weak market pressures, factor price distortions and so on. Though these factors may be operating at different degrees, the existence of scale economy should be stressed in case of the iron and steel industry. LDCs tend to prefer large-scale ironmaking equipment. The reason is that, even if not adapted to domestic factor prices, large-scale equipment enables LDCs to achieve a substantial reduction in unit production cost.

The plan of this paper is as follows. In Section II, the process of importation of advanced technology is briefly described. Section III and IV are devoted to the examination of technology adaptation; Japan is dealt with in the former section, and Brazil and India in the latter section. In Section V, several causes for non-adapted borrowed technology are discussed.

II. A Brief Description of the Process of Importation of Foreign Technology

A. Indigenous Iron and Steel Industry

*Tatara-buki*, which refined iron sand within furnaces by using charcoal, was the prevailing way of producing iron in Japan before the Meiji Era. The traditional method however could not meet, both in quantity and quality, the demand for steel which was increasing mainly due to military needs. To satisfy the expanding demand, the feudal government and several feudal clans imported modern methods of producing iron such as reverberating furnaces for making steel and blast furnaces for making pig iron, both of which were largely different from the traditional method.

India and Brazil also have long metallurgical traditions. In India, the method of smelting and fashioning iron, perhaps introduced from China, was known to the people from early times. They produced with diminutive furnaces small blooms of soft iron used chiefly for ax-heads and ploughshares. Even in the 1910s, this method was practiced as an indigenous industry in widely scattered areas, and in the Central Provinces alone, for example, nearly 4,500 tons of iron ore were smelted in as many as 300 native furnaces. The traditional technique could not compete with the modern technique, because it was a

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8 H.L. Dey (1), pp. 150–151.
wasteful way of production consuming larger quantities of ore and fuel. The first effort to produce steel along modern lines was made by J.M. Heath in 1830 under financial aid from the East India Company. Until the Tata Iron and Steel Company (henceforth abbreviated as TISCO) was founded in 1907, there existed a lot of attempts to introduce modern techniques similar to those used in the West, but most of them failed. Causes for the failures were insufficient government protection, charcoal shortages, higher cost of iron due to using charcoal, and so on.

In Brazil which possesses the rich ores of Minas Gerais, small furnaces had been operated to produce forgeable iron since colonial times (the beginning of the sixteenth century), but even in the early twentieth century most of her demand for steel was still satisfied by imports from abroad. With the cessation of steel imports during World War I, the necessity of domestic production was keenly felt. In 1921 a Belgian established an ironworks with charcoal-fired furnaces, Companhia Siderúrgica Belgo-Mineira (CSBM), which was a pioneer of the modern steel mill in Brazil, though founded by a foreigner.

Owing to her isolation policy, Japan was in a more difficult position to obtain modern technology than Brazil and India which were colonies of then advanced countries. Consequently it was from a book written by U. Huguenin that Japan learned modern ironmaking technology before the Meiji Era. Japanese technicians in those days tried to construct furnaces on the basis of their technological knowledge obtained from the book, which experience seemed to have served to modify the modern equipment imported from England in the early Meiji period.

B. Importation of Modern Processes of Iron Manufacture

Ambitious attempts were made by the Meiji government to transplant modern techniques with the intention of building a richer nation and a stronger army. Government-run ironworks were established at Kamaishi and Nakaosaka. However, both of them were closed in 1882, shortly after their establishment, due to insurmountable initial difficulties. After they were sold off to private interests, the ironworks at Kamaishi alone succeeded as a private enterprise, which will be referred to as Tanaka Ironworks in this paper. The relationship between private and government-run ironworks was not such that the former proceeded on the path beaten by the latter which broke new ground. It was partly owing to the prior success of private ironworks that government officials, who were discouraged by the failures of early attempts, decided to establish another ironworks at Yawata as a government enterprise. When furnaces there were operated in 1901, some of the skilled workers at Kamaishi were sent to Yawata to help operations. After the Russo-Japanese War, many private firms solely engaged in steelmaking with open hearths were established. Thus the rapid expansion of the Japanese iron and steel industry can be attributed to the growth of private as well as government-run enterprises.

In prewar India, most attempts to borrow advanced ironmaking technology were made by private enterprises. It was difficult for the government of India to take active measures

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4 The Bengal Iron and Steel Company was an exception. It could pay dividends in 1899, ten years after it took over the business of the Barakar Iron and Steel Company.
5 T. Hata et al. (10), p. 8.
6 Brazil became independent from Portugal in 1822.
7 The Mysore Iron and Steel Works (MISW) established in 1918 is an exception. This ironworks was owned by Mysore state government.
to develop the industry, because the British government adhered to the principle of laissez-faire as a colonial policy. The epochmaking discovery of the "Iron Belt" in 1905 led to the formation of two big companies, i.e., TISCO (1907) and IISCO (Indian Iron and Steel Company, 1918), the former being the first fully successful Indian steel mill. In the days when TISCO began its operation, however, there prevailed a notion of self-reliance of private enterprises. It was true that the government of India was keenly interested in the growth of TISCO and therefore gave the company the necessary facilities in many directions, but the attitude of the government was one of simple approval and moral support, and did not in any way amount to a promise of financial assistance in any shape or form.

Japanese ironworks in the Meiji Era can be characterized by a short period of dependence upon foreign technicians and skilled workers. After being employed for the establishment of ironworks, they were successively discharged because of their inability. As a result, it took about ten years after the inaugural kindling of the first blast furnace for the ironworks at Yawata to record positive profits. In contrast to this, TISCO made positive net profits immediately after the beginning of operation in 1911 (see Fig. 1 and Table 1). TISCO was an enterprise financed by the money of the Indian public and managed by "Swadeshi" brains, and yet the operation of blast furnaces, steelmaking furnaces, and rolling

**FIG. 1 CHANGES IN PROFITS OF YAWATA IRONWORKS**

![Graph showing changes in profits of Yawata Ironworks](image)

*Note:* Profits in this figure include interest payments as well as depreciation.

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8 It was in the 1920s that the protection policy was adopted for the Indian iron and steel industry.
9 H.L. Dey (1), p. 163.
mills were practiced and supervised by Americans and Europeans.\textsuperscript{10} The entire dependence upon skilled workers and technicians during the initial period, together with superior quality of Indian ores,\textsuperscript{11} could explain why TISCO achieved such an early success in making profits.

During the post-World War II period, the Indian government which has been committed to growth through central planning has been intent on importing advanced technology through the formation of government-run ironworks. Public sector steel mills were established especially during the Second Five Year Plan which began in 1956 and gave high priority to heavy industry. They were Rourkela, Bhilai and Durgapur, which owed financial and technical assistance to West Germany, the Soviet Union and the United Kingdom respectively. The amounts of investment funds borrowed from these countries are shown in Table 2, ranging from 37 to 65 percent of the foreign exchange requirements. In case of state-run and private steel mills, loans from the World Bank were available. Interest rates were low, being 6 percent in Rourkela, 2.5 percent in Bhilai, and 4.75 percent in IISCO. The Indian government in the postwar period gave financial assistance to private steel mills

\textbf{Table 1. Profits and Dividends of TISCO, 1912–13 to 1921–22}

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Profits (1000Rs)</th>
<th>Depreciation (1000Rs)</th>
<th>Net Profits (1000Rs)</th>
<th>Percentage of Dividend on Ordinary Shares (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912–13</td>
<td>859</td>
<td>200</td>
<td>659</td>
<td>nil</td>
</tr>
<tr>
<td>1913–14</td>
<td>2,264</td>
<td>350</td>
<td>1,914</td>
<td>6</td>
</tr>
<tr>
<td>1914–15</td>
<td>2,483</td>
<td>300</td>
<td>1,983</td>
<td>8</td>
</tr>
<tr>
<td>1915–16</td>
<td>6,830</td>
<td>1,070</td>
<td>5,760</td>
<td>15</td>
</tr>
<tr>
<td>1916–17</td>
<td>11,077</td>
<td>3,500</td>
<td>7,577</td>
<td>20</td>
</tr>
<tr>
<td>1917–18</td>
<td>10,570</td>
<td>4,781</td>
<td>5,789</td>
<td>20</td>
</tr>
<tr>
<td>1918–19</td>
<td>6,718</td>
<td>2,490</td>
<td>4,228</td>
<td>7</td>
</tr>
<tr>
<td>1919–20</td>
<td>11,531</td>
<td>6,145</td>
<td>5,386</td>
<td>16</td>
</tr>
<tr>
<td>1920–21</td>
<td>11,695</td>
<td>6,452</td>
<td>5,243</td>
<td>16</td>
</tr>
<tr>
<td>1921–22</td>
<td>8,837</td>
<td>4,100</td>
<td>4,737</td>
<td>4</td>
</tr>
</tbody>
</table>


\textbf{Table 2. Financial Aid from Abroad under the Second Five Year Plan}

<table>
<thead>
<tr>
<th>Name of Steel Mills</th>
<th>Necessary Foreign Exchange for Purchasing Plants and Equipment</th>
<th>Amount Borrowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government-run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rourkela</td>
<td>1,330</td>
<td>750 (from West Germany)</td>
</tr>
<tr>
<td>Durgapur</td>
<td></td>
<td>350 (from United Kingdom)</td>
</tr>
<tr>
<td>Bhilai</td>
<td>950</td>
<td>620 (from Soviet Union)</td>
</tr>
<tr>
<td>State-run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MISW</td>
<td></td>
<td>10 (from World Bank)</td>
</tr>
<tr>
<td>IISCO</td>
<td>950</td>
<td>512 (from World Bank)</td>
</tr>
<tr>
<td>Private</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TISCO</td>
<td>950</td>
<td>245 (from World Bank)</td>
</tr>
</tbody>
</table>


\textit{Note:} MISW means the Mysore Iron and Steel Works.

\textsuperscript{10} L. Fraser (4), pp. 64, 81 and 83.

\textsuperscript{11} The iron content of Indian ore is more than 60 percent.
as well. The 1952 expansion program of TISCO, for instance, required 430 million rupees for investment, about a fourth of which was lent by the government without interest during the construction period.

In India, as was in Japan, government-run ironworks were preceded by private ones. Just as Yawata was benefited by the supply of skilled workers from the Tanaka Ironworks, new public sector mills in India were also favoured by the prior existence of TISCO and IISCO, drawing heavily upon the reservoir of skills accumulated by these companies during the past half century. Private steel mills not only helped public sector mills to obtain skilled workers, but also participated in central planning for attaining the production targets of the government. However, in the Third Five Year Plan, the Indian government did not allow private ironworks to expand their production capacity, on the expectation that Third Plan targets could be met by expansion of existing public sector mills and the erection of a new government-owned mill at Bokaro.

For the LDC economies including Meiji Japan, the establishment of a steel mill is to some extent a manifestation of economic nationalism. The Companhia Siderúrgica Nacional (CSN), which was founded in 1941 by the government and which started to operate in 1946, is the first coke-using steel mill in Brazil. Getulio Vargas, the dictator in those days, emphasized national unity and pushed forward a vigorous program of economic development, which led to the formation of CSN. The technical and economic planning of the plant and its construction were carried out by American firms. Dollar exchange necessary for purchasing the plant from the United States amounted to 45 million dollars, which was financed by the Export-Import Bank at 4 percent interest. With the same intention, other ironworks with coke-operated blast furnaces such as USIMINAS (Usinas Siderúrgicas de Minas Gerais) and COSIPA (Companhia Siderúrgica Pautista) were founded after World War II with the assistance of Japanese and European firms.

In the case of the Brazilian steel mills, a protracted dependence upon foreign workers was also indispensable. In establishing USIMINAS, for instance, as many as 200 Japanese technicians and skilled workers were sent to Brazil to help construction and subsequent operation, and eight Japanese experts have remained there to provide technical instructions. CSN and USIMINAS invited technicians and skilled workers from the United States and Japan respectively, whereas COSIPA sent Brazilian workers to Europe for training. The way of training adopted by COSIPA does not seem successful, judging from the fact that the equipment of COSIPA is operated at considerably less than capacity. In 1973, there was only a minor difference in annual capacity for producing steel between COSIPA and USIMINAS, but the production of steel ingots by the former was nearly half that by the latter.

A similarity exists between Brazil and India in that private ironworks coexist with government-run ironworks. The top five companies are CSN (using coke), USIMINAS (coke), COSIPA (coke), CSBM (charcoal), and Mannesmann (both coke and charcoal), the first three of which are government-owned. The share of these government enterprises in the production of steel ingots is very large, being about 50 percent in 1973. The govern-

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12 W.A. Johnson (11), p. 42.
13 W.A. Johnson (11), p. 81.
15 See Table 6 which will be shown later.
ment policy for the iron and steel industry is diffused to other parts of the industry through the channel of the three big government ironworks.

III. Technology Adaptation: The Experience of Japan

A. Adapted Borrowed Technology

As was mentioned in the previous section, the government-run ironworks at Kamaishi was sold in 1885 to an iron dealer, Chobei Tanaka. At the outset, he bought charcoal and ore from the government and installed a small blast furnace because the 25-ton furnace which the government imported from England was too large for him to operate. In this small furnace he initiated a test series, and succeeded in producing pig iron in 1886. This success encouraged him to establish a private iron-manufacturing company (Tanaka Ironworks at Kamaishi). In 1892, blast furnaces of this company numbered five, whose maximum capacity was less than 5 or 6 tons per day per furnace.

A reduction in furnace size from 25 tons to less than 5 or 6 tons, which was due to the lack of experience in operating a modern blast furnace, enabled the modification of ancillary equipment of a furnace. Comparison between equipment reveals such differences, as shown in Table 3. This table shows a clear contrast between government-run and privately-managed ironworks at Kamaishi. In the former a blower made of iron was driven by steam power, while in the latter, air blast was produced by a method similar to the traditional one, but hot blast stoves were used for preheating the blast. The only exception was a furnace built at the Suzuko branch of Tanaka Ironworks, where steam power was employed to produce air blast. Thus, in general, it is clear that the modification of ancillary equipment lowered capital-labor ratios. Water wheels were gradually replaced with steam engines, but

<table>
<thead>
<tr>
<th>Source of Power</th>
<th>Blowing Equipment</th>
<th>Hot Blast Stove</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional method (Tatara-buki)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western small-scale blast furnace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government-run ironworks at Kamaishi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanaka Ironworks at Kamaishi (between 1885 and 1891)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: 1 Fuji Seitetsu (6), p. 36 and Nippon Kogakukai (15), pp. 81-82. 2 Nippon Kogakukai (15), p. 66. 3 Fuji Seitetsu (5), p. 11 and (6), pp. 77 and 93. 4 Fuji Seitetsu (6), pp. 77 and 111-112. 5 Fuji Seitetsu (5), p. 23 and Saigusa and Iida (23), pp. 38-39. 6 Fuji Seitetsu (5), p. 50 and Saigusa and Iida (23), pp. 94-95.

Note: * A steam boiler was used at the Suzuko Branch of Tanaka Ironworks.
at the Kurihashi branch where plenty of charcoal was available, they were still used even in the early 1900's.

Modification was made in subsidiary as well as main production processes. In the government-run ironworks at Kamaishi, rails and steam locomotives were imported to transport coals and iron ores. When it was closed, these facilities were sold for laying a railway between Osaka and Sakai. Therefore, in establishing an iron-manufacturing company, Tanaka had to reconstruct the transporting facilities, but by means of carts and horse-tramways which were less expensive than railways.

The term "technology" should rather involve not only a method of production which is embodied in equipment but also experience (or skill) necessary for operating equipment or processing materials and fuels. Borrowed "technology" often simply means borrowed "production method," but the above-mentioned fact that the government-run ironworks at Kamaishi failed to produce pig iron with imported modern equipment suggests that the absence of experience was an obstacle to production. Successful borrowed technology should include imported experience as well as imported production method. The government-run ironworks tried to introduce the necessary experience which was embodied in English technicians and skilled workers. However, this attempt did not succeed partly because they had no specific knowledge about the characteristics of Japanese coal and iron ore.

The curves labeled as $\alpha$ and $\beta$ in Fig. 2 are the isoquants corresponding to different output levels. In the case where increasing returns to scale operate, a proportionate in-

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**FIG. 2 ADAPTATION OF BORROWED TECHNOLOGY**

![Diagram](attachment:image.png)
crease in all factor inputs leads to a more than proportionate increase in output. Fig. 2 shows that, at a given factor proportion, capital and labor employed on the \( \alpha \) curve are \( \gamma \) times those on the \( \beta \) curve, and that the output produced on the former is \( \gamma^n \) times that on the latter, where \( "n" \) is greater than unity because of scale economies.

Point A on the \( \alpha \) curve indicates an imported 25-ton blast furnace equipped with a steam-driven iron blower and hot blast stoves. The size of this furnace was too large, so that it was far beyond the experience which had been obtained by operating traditional or small-scale Western furnaces before the Meiji Era. In the Tanaka Ironworks, therefore, furnaces were scaled down to the feasible size which was within the past experience. Point B on the \( \beta \) curve indicates a 5 or 6-ton furnace adopted by this ironworks.

Our basic hypothesis here is that a large-scale equipment requires an additional experience (or skill) to operate because of technical, organizational and operational characteristics specific to it; that is, the \( \alpha \) curve presupposes a further accumulation of experience, while the \( \beta \) curve does not. So long as experience remains at the level acquired in the past, the \( \beta \) curve alone is available to entrepreneurs.

Our interpretation is that Point B was chosen along the \( \beta \) curve so as to minimize the cost per unit of output by taking the domestic wage-rental ratio \((\omega/\pi)\) into consideration. This method of production was different from an imported as well as a traditional one in that hot blast stoves, which had not been employed until they were imported from England, were combined with a traditional method of producing a blast, i.e., water-powered wooden bellows. Thus we can say that the production method indicated by Point B is a modified or adapted borrowed technology.

B. Shift from Adapted to Non-adapted Borrowed Technology

To my mind, the Tanaka Ironworks at Kamaishi for the period 1885-1891 provided an example of adapted borrowed technology. However, in the subsequent years, it shifted from adapted to non-adapted borrowed technology. This shift can be inferred from the following evidences:

(a) In the early days of the Tanaka Ironworks, the charge of coke and ore was raised up to furnace-mouths by hand, but afterwards by steam power or electricity.

(b) Wooden bellows were gradually replaced by iron blowers to avoid losses of air blast, which enabled the attainment of a higher working temperature in furnaces.

(c) In 1893, one of the 25-ton blast furnaces which were bought from the government but not used until then started to operate. This fact means that the workers at Kamaishi had accumulated enough experience to operate a large-scale furnace. In 1901, another 25-ton furnace equipped with a steam-driven iron blower was operated.

(d) In 1904, the 60-ton furnace was used, and after World War I, the size of furnace increased further, even to a daily capacity of 120 tons of pig iron.

(e) The increase in furnace size required larger quantities of material and fuel, so that transporting facilities also had to be improved. At the end of the Meiji Era, railroads were

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16 As for the diagrammatical presentation given in the text, see R.T. Gill (8), Ch. 5.
17 A blast furnace is an often quoted example of increasing returns to scale, because the volume of a furnace increases more rapidly than the enclosing surface.
The problem to be answered is why the Tanaka Ironworks shifted to non-adapted borrowed technology. Government-run ironworks both at Kamaishi and Yawata imported advanced equipment without modifying it. Unlike private firms, government enterprises which could afford to be more or less indifferent to cost minimization might have been inclined to install the latest plants which were more capital-intensive than that warranted by the relative factor prices prevailing in the domestic markets. It should be noticed, however, that the Tanaka Ironworks was a private enterprise. This fact signifies that a shift to non-adapted borrowed technology was irrelevant to the organizational form of enterprise, i.e., whether it was privately managed or not.

Returning to Fig. 2, a firm which has accumulated the experience necessary for operating a large-scale equipment is able to make a choice between Point C which minimizes the unit production cost along the $\alpha$ curve and Point A which is an imported capital-intensive method. Under given factor prices, the unit cost at Point C, $(\omega_1 L_0 + \pi^T K_0)/Q_0$, is less than that at Point A, $(\omega_1 L_1 + \pi^T K_1)/Q_0$. Therefore, Point C may seem to be preferable to Point A. However, Point C is risky because it has not yet been tried or tested in advanced countries, and the development of Point C may require a lot of time and money but may not be of practical use. In contrast to this, the adoption of Point A is a riskless and prompt way of enlarging a firm even though the unit production cost is higher in A than in C.

Our explanation for the shift to non-adapted borrowed technology is given in the above analysis. When there exists a substantial degree of scale economy, that is, when $n$ is very large, a firm may shift from B to A, not to C, because A is less risky than C, and also because A warrants a lower unit cost than B (the unit cost at Point A, $(\omega_1 L_1 + \pi^T K_1)/Q_0$, will be far smaller than that at Point B, $(\omega_1 L_0 + \pi^T K_0)/Q_0$, if $n$ is very large.) On the contrary, when scale economies exist but only to a slight extent, a shift from Point B (adapted borrowed technology) to Point A (non-adapted borrowed technology) does not profit a firm. Therefore, in using the $\alpha$ curve, technology adaptation to domestic factor prices should be made, that is, Point C should be chosen and developed, if an increase in unit cost is to be avoided.

IV. Examination of Indian and Brazilian Steel Mills

A. The Case of India

The equipment of TISCO at the time of kindling of the first blast furnace (in 1911) was as follows:21

a) coke ovens with the necessary equipment for the crushing and handling of coal,
b) two blast furnaces, each of 350-ton capacity per day, with hot blast stoves, dust-catchers, automatic skip-hoists for charging materials,
c) six open hearth furnaces, four of which are of 50-ton capacity and two of 60-ton capacity, and
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d) blooming and rolling mills.

A comparison reveals that TISCO was equipped with more capital-intensive, and therefore more up-to-date machines than Yawata. It started to operate in 1901 with equipment composed of old-fashioned coke ovens of Beehive type, one 160-ton blast furnace, four 25-ton open hearth furnaces, and so forth. TISCO's equipment in the subsequent years became more modern, reaching a scale which included a 1,200-ton blast furnace and 200 or 250-ton open hearth furnaces before World War II.22

Table 4. Planned Equipment of Public Sector Steel Mills Under India's Second Five Year Plan

<table>
<thead>
<tr>
<th>Name of Steel Mills</th>
<th>Daily Capacity and Number of Blast Furnaces</th>
<th>Capacity and Number of Steel-making Furnaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rourkela (West Germany)</td>
<td>1,000-ton $\times$ 3</td>
<td>80-ton open hearth $\times$ 4</td>
</tr>
<tr>
<td>Bhilai (Soviet Union)</td>
<td>1,135-ton $\times$ 3</td>
<td>40-ton LD converter $\times$ 3</td>
</tr>
<tr>
<td>Durgapur (United Kingdom)</td>
<td>1,250-ton $\times$ 3</td>
<td>250-ton open hearth $\times$ 6</td>
</tr>
</tbody>
</table>

80-ton open hearth $\times$ 4
100-ton open hearth $\times$ 1
200-ton open hearth $\times$ 7


For the postwar period, Table 4 shows the planned equipment of public sector steel mills under the Second Five Year Plan. As of July 1960, TISCO which had already accumulated skills for production was operating a 1,650-ton blast furnace, whereas the daily capacity of blast furnaces installed in new public sector steel mills was between 1,000 and 1,250 tons of pig iron, being smaller than that of TISCO. In 1957, pig iron produced per day per furnace was on average 960 tons in the United States, 925 tons in Japan, and 918 tons in the Soviet Union.23 Therefore, unless furnaces in these countries were operated at considerably less than capacity, blast furnaces in the new Indian steel mills were comparable to those of average-sized mills in the advanced countries.

It seems undeniable that the machines in the main production process were imported without modification. Therefore, technology adaptation had been confined, if any, to the subsidiary production processes such as mining, transportation, material handling, construction, and so on. A photograph of prewar Indian mining shows that workers carried materials on their heads from mountain to freight cars.24 As a postwar example, in building ironworks at Bhilai with the assistance of the Soviet Union, it was agreed upon that they should use as much cement as possible instead of steel.25 This substitution must have lowered construction costs.

However, some evidences suggest that even in the subsidiary production processes equipment was highly mechanized. Initially, TISCO tried to minimize its investment in machinery by using coolie labor especially in the handling of materials,26 but it was found,

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22 T. Hata et al. (10), p. 170.
23 Nippon Tekko Renmei, Tekko Tokei Inkai (17), pp. 113-114.
24 V. Elwin (3), p. 46.
26 W.A. Johnson (11), p. 46.
perhaps at the planning stage, that coolie labor did not serve as a useful substitute for machinery. The machine adopted for handling materials was extraordinarily capital-intensive. Of labor-saving devices, the coke ovens and the coal crushing plant furnish a typical example. "The coal is carried mechanically into the crushers and having been so pulverised that the proportion which will equal the size of a pea will be less than one percent, it is shot up into an elevator from which it is discharged into wagons for conveyance to the coke ovens. . . . The rams which drive the coals into the ovens, the levellers by which the coal is spread inside the ovens, and the pushers by which the coke is ejected from the ovens are all electrically driven, and the coal is scarcely touched by human hands from the moment of its arrival from the Jherria coal-fields to the time when it is shunted to the blast furnaces yard." In Rourkela, as another example, mining was mechanized, materials were carried by railways, and Diesels were used for interplant transportation.

As was mentioned in section II, prewar TISCO employed a large number of foreign skilled workers. Since their wages were much higher that those of Indian workers, total wage cost increased as compared with what would have been if equipment had been operated by Indian alone. This fact, however, does not suffice to justify the importation of capital-intensive methods, for the cost of wages to be saved by replacing foreigners by Indian workers is estimated at 2.23 million rupees in the year 1925–26, being only a 15 percent reduction in total wage bill. Subsequently the number of foreign workers decreased, while the equipment became increasingly capital-intensive, which fact also demonstrates that the employment of high-salaried foreigners was not a decisive reason for non-adapted borrowed technology.

B. The Case of Brazil

For postwar Brazil, detailed information on equipment is available. Table 5 summarizes the daily capacity of blast furnaces of major government-run steel mills, showing increases in furnace size for a decade. Generally speaking, most Latin American countries are dependent upon importation from advanced countries for ironmaking equipment. To

<table>
<thead>
<tr>
<th>Name of Steel Mills</th>
<th>Year of Beginning Operation</th>
<th>In the Early 1960s</th>
<th>At the End of 1974</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSN (U.S.A.)</td>
<td>1946</td>
<td>1,200 or 1,400-ton × 2</td>
<td>{1,750-ton × 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>{1,900-ton × 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>{1,400-ton × 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>{1,500-ton × 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>{4,300-ton × 1</td>
</tr>
<tr>
<td>USIMINAS (Japan)</td>
<td>1962</td>
<td>700-ton × 2</td>
<td>unknown</td>
</tr>
<tr>
<td>COSIPA (France and West Germany)</td>
<td>1963</td>
<td>2,000-ton × 1</td>
<td>unknown</td>
</tr>
</tbody>
</table>

Source: The data on equipment in the early 1960s are from Tekko Kaigai Shijo Chosankaikai (24), pp. 50–60, and those at the end of 1974 from M. Oishi (20), pp. 13–14.

87 L. Fraser (4), p. 67.
take USIMINAS as an example, coke ovens, sintering machines, blast furnaces, blooming mills, plate rolling mills and continuous casting equipment were all imported from Japanese manufacturers without modifying them to suit the factor prices prevailing in Brazil, though some of the equipment such as Diesels, gas-holders, LD converters, and hot strip mills were purchased from the United States and European countries.

When Japanese technology was imported by USIMINAS, the capacity of blast furnaces was scaled down to the average size in Japan. Its blast furnaces were only of 700-ton capacity per day in 1962 (see Table 5), or less than half that which Yawata Ironworks operated at the Tobata branch in 1959. Scaling down was needed not for the narrowness of domestic markets but for technical reasons, i.e., because the larger the furnace size, the more difficult it is to operate. It should be remembered that the Tanaka Ironworks also decreased the size of its furnace from 25 to 5 tons of pig iron in order to overcome some initial difficulties in the early Meiji period. In the case of the Tanaka Ironworks, however, scaling down involved technology adaptation, while in case of USIMINAS, no adaptation was made to the Brazilian factor prices.

The reduction in furnace size surely lowered establishment costs, but scaling down was only for a short period after the beginning of operation. In the subsequent years, the blast furnace capacity of the Tanaka Ironworks increased successively from 5 tons of pig iron per day per furnace in 1885 to 120 tons per day per furnace after World War I. A similar tendency can be observed in USIMINAS. After ironmaking skills were accumulated by operating scaled down equipment, there occurred a remarkable increase in furnace size; the largest daily capacity of a blast furnace was 700 tons in 1962, 900 tons in 1966, 1,500 tons in 1973, and 4,300 tons in 1974.

An outstanding feature of the Brazilian iron and steel industry is that a considerable part of pig iron is still produced by charcoal-fed blast furnaces. This is due to the favorable natural environment where trees (eucalyptus) grow fast to a diameter large enough for cutting. The use of charcoal as fuel restricts the size of the blast furnace. Generally, a furnace

<table>
<thead>
<tr>
<th>Year of Initial Kindling</th>
<th>Volume of a Furnace (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Steel</td>
<td>1915</td>
</tr>
<tr>
<td>Gutehoffnungshütte</td>
<td>1912</td>
</tr>
<tr>
<td>Yawata</td>
<td>1910</td>
</tr>
</tbody>
</table>


It is said that the average volume per blast furnace in the United States was about 400 m³ in those days (see The Ministry of International Trade and Industry (ed.) (13), p. 160). Therefore, the volume of the largest furnace at Yawata was nearly comparable to the average in the United States. As for the Indian steel mills, see (A) of this section.


In Japan it was only at the beginning stage of operation that charcoal was used as fuel in the blast furnaces at Kamaishi. In India, the Mysore Iron and Steel Works alone operated a charcoal-fed furnace still in the 1930s.
is smaller in scale and hence simpler in mechanism in charcoal-fed than in coke-fed furnaces; materials are raised up to furnace-mouts by hand (not by electricity), gauges indicating the condition inside the furnace are lacking or are simplified, and hot blast stoves and other ancillary equipment are less expensive. This means that technology adaptation is made to suit the Brazilian factor prices. The difference in fuel is reflected in equipment, which in turn determines labor productivity. A comparison between the firms possessing ore deposits clearly indicates a lower labor productivity in charcoal-using ironworks (Table 6).

**Table 6. Comparison of Steel Ingots per Person between Major Integrated Steel Mills in Brazil**

<table>
<thead>
<tr>
<th>Name of Steel Mills</th>
<th>Ownership</th>
<th>Kind of Pig Iron</th>
<th>Ore Deposits</th>
<th>Steel Ingots per Total Engaged Persons (ton per person) in 1973</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSN</td>
<td>public</td>
<td>coke pig</td>
<td>possessed</td>
<td>89</td>
</tr>
<tr>
<td>USIMINAS</td>
<td>public</td>
<td>coke pig</td>
<td>not possessed</td>
<td>184</td>
</tr>
<tr>
<td>COSIPA</td>
<td>public</td>
<td>coke pig</td>
<td>not possessed</td>
<td>91</td>
</tr>
<tr>
<td>Mannesmann</td>
<td>private</td>
<td>coke pig</td>
<td>possessed</td>
<td>67</td>
</tr>
<tr>
<td>CSBM</td>
<td>private</td>
<td>charcoal pig</td>
<td>?</td>
<td>76</td>
</tr>
<tr>
<td>ACESITA</td>
<td>public</td>
<td>charcoal pig</td>
<td>possessed</td>
<td>44</td>
</tr>
</tbody>
</table>

Sources: Steel ingots per total engaged persons are calculated from M. Oishi (20), pp. 11 and 13-14. Other columns are from Tekko Kaigai Shijo Chosa Inkai (24), pp. 50-57.

Notes: 1) Total engaged persons include those who work in mining, construction and transportation. 2) It is not certain whether CSBM possesses its own ore deposits or not.

Brazilian low wages allow the existence of low productivity firms with less capital-intensive equipment.

The iron and steel industry in Brazil could be characterized by the coexistence of large-scale ironworks producing coke-made pigs with highly modern equipment and relatively small-scale ironworks producing charcoal-made pigs with less capital-intensive equipment. Coke-pigs increased their share of total production, however, as is indicated by the recent trend that the share of pig iron produced by CSN, USIMINAS, and COSIPA, each of which is operating coke-furnaces, rose from 42 percent in 1958-62 to 55 percent in 1968-72. Moreover, it should be noticed that some ironworks producing charcoal-pigs began to blend coal with coke, or planned to build coke-fed furnaces. The basic reason for those changes lies in the fact that the use of charcoal restricts the furnace size because charcoal is easily crushed into powder under the pressure of charges in the furnace, so that ironworks cannot enjoy scale economies which enable a reduction in the unit cost.
V. Causes for Non-adapted Borrowed Technology

Several causes can be pointed out to explain why LDCs tend to employ highly capital-intensive methods of production in spite of their resource endowments characterized by an abundant supply of labor and a scarcity of capital. They are: (1) technological fixity, (2) availability of capital markets in advanced countries, (3) lack of competitive market pressures, (4) factor price distortions, and so forth. These factors are all operating in one degree or another, but a brief discussion is necessary.

(1) Technological fixity is very often mentioned as a key factor for explaining minor adjustments of capital intensity in LDCs. It is emphasized from an engineering viewpoint that factor substitution is limited to a narrow range. R.S. Eckaus also stressed fixity, though from a slightly different standpoint. According to him, entrepreneurs in LDCs are apt to believe that the "Western way" of producing, which involves high ratios of capital to labor, is the best and only way, so there is no room for adjusting it to the factor prices prevailing in their countries. In other words, whatever the actual characteristics of the production function may be, they believe that the production function which they face is a limitational one in which no substitution is possible. However, some counter-evidences could be shown against this hypothesis. As was shown in the previous sections, the Tanaka Ironworks at Kamaishi in the early Meiji period and many charcoal-fed furnaces still operated in Brazil are fine examples of technology adaptation in which capital-labor ratios are lowered to a considerable extent in comparison with the advanced technology imported from abroad without modification. Thus, the problem to be solved is why entrepreneurs in LDCs tend to switch from labor-intensive methods of production suited to the domestic factor prices to capital-intensive methods not suited to them.

(2) Capital markets available to LDCs are not confined to their domestic markets. A part of the funds necessary for investment can be borrowed from capital markets abroad. Since interest rates charged on borrowed money are lower in advanced countries, LDCs are justified in using more capital-intensive methods than would be otherwise. It seems unlikely, however, for LDCs to depend entirely upon advanced countries for investment funds. Table 2 in section II shows that under the Second Five Year Plan, public sector steel mills in India borrowed not total amount, but one-third to two-thirds, of foreign exchange requirements from advanced countries. The same is true in the case of Brazil. Though she depended on foreign capital markets, the percentage of interest payments in total cost of steel product was 11 percent in 1966, being much higher than that in Europe (4 percent) and in the United States (1 percent). This was partly due to a high rate of interest (22 percent in 1967) on loans by BNDE (National Bank of Economic Development) which is the important financial institution to the iron and steel industry in Brazil. The high percentage of interest payments suggests that the resource endowments in the Brazilian economy are reflected in its relative factor prices. Therefore, it would still be desirable for steel manufacturers in Brazil to use less capital-intensive methods.
(3) Competitive market pressures urge entrepreneurs to make efforts at minimizing production costs, while a lack of pressure results in non-adapted borrowed technology, that is, a failure to choose efficient production methods. Iron manufacturers in LDCs, who seem to exert monopolistic power in domestic markets, are usually under competitive pressure from abroad. For example, ironworks in prewar Japan have long been exposed to competition from foreign countries. Competition was severe especially in the market for pig iron, because the imposition of tariff on it was thought to obstruct the growth of domestic metal-using industries. Nevertheless, production methods were not adapted to factor prices for most of the prewar years, and became more and more capital-intensive. Therefore the adoption of highly capital-intensive methods in Japan is not attributable to weak competitive pressures in product markets.

(4) Capital subsidies, interest rates artificially pegged low, duty-free importation of capital equipment, the minimum wage, and so on, tend to cheapen capital and make labor dearer, inducing entrepreneurs in LDCs to choose more capital-intensive methods of production. These policy measures for distorting factor prices were emphasized by R.H. Mason in his discussion on the factor proportions problem. Within our scope of research, however, TISCO and the Tanaka Ironworks in the prewar period seem to be exceptions. The description in section II clarifies that TISCO purchased the latest equipment with the money of the Indian public, and increased the size of furnaces without financial support of the government. It was because self-reliance of private enterprises was the basic doctrine followed by the Indian government until the necessity of protection of the Indian iron and steel industry was recognized by the British government in the 1920s. The Tanaka Ironworks, on the other hand, bought ironmaking equipment from the government at cheap prices. However, the expansion of equipment in subsequent years was made, similarly, without protection by the government until the Steel Industry Promotion Act was established

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*S.A. Morley and G.W. Smith took this factor into consideration as one of the possible explanations of highly capital-intensive methods adopted by multinational firms (see (14), p. 264).

*Large quantities of pig iron were imported from India after the beginning of the 1910s, and in 1929 reached to the highest level, 62.9 percent of pig iron imported by Japan (T. Hata et al. (10), pp. 200-201). This was due to cheap prices of Indian pig iron. The table below, though compiling the postwar data, shows that unit material costs are remarkably lower in India.

**COMPARISON OF UNIT MATERIAL COSTS (IN 1957-58) AND DOMESTIC PRICES (IN 1960) OF PIG IRON**

<table>
<thead>
<tr>
<th>Countries</th>
<th>Unit Material Costs</th>
<th>Domestic Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coke</td>
<td>Ore</td>
</tr>
<tr>
<td>India</td>
<td>11.5</td>
<td>5.0</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>14.8</td>
<td>22.4</td>
</tr>
<tr>
<td>West Germany</td>
<td>18.1</td>
<td>24.8</td>
</tr>
<tr>
<td>U.K.</td>
<td>20.7</td>
<td>22.8</td>
</tr>
<tr>
<td>Japan</td>
<td>20.9</td>
<td>23.9</td>
</tr>
<tr>
<td>France</td>
<td>23.9</td>
<td>26.5</td>
</tr>
<tr>
<td>Belgium</td>
<td>26.2</td>
<td>29.6</td>
</tr>
</tbody>
</table>


*Notes:* a) is retention prices (prices paid to producers) and b) is selling prices (prices paid by consumers).

<sup>40</sup> R.H. Mason (12).
in 1918 for the purpose of protecting private iron and steel manufacturers.41

The above exception may not be sufficient to deny the validity of the factor distortions hypothesis, for other examples can be shown in which the choice of capital-intensive methods in LDCs was closely associated with distorted factor prices. It should be added, however, that factor price distortions presuppose more basic causes which could be traced back to, say, general backwardness. They are, to put in the context of our analysis, a lack of scientific knowledge indispensable to the search for production techniques suited to LDCs, and a deficiency of funds necessary to develop these techniques to the level of practical use.42 They cause LDC economies to distort factor prices so that capital-intensive equipment can be easily purchased.

Borrowing of advanced technology has the advantage of saving both time and money which would be required if LDCs tried to develop their own production methods. It also enables LDCs to avert the risk of failure involved in research and development activities. Another advantage is that, even if not adapted to domestic factor prices, modern technology lowers the cost per unit of output to a great extent. Especially in case of the industry considered, the existence of scale economy tends to lead to the adoption of capital-intensive methods, because these bring about a substantial reduction in unit production cost. If the above discussion is correct, two inferences follow.

1. If technology adaptation is made, it will be in the industries where scale economies do not exist at all, or exist only to a slight extent. The raw silk industry in prewar Japan provides a typical example.

2. The iron and steel industry cannot be expected to increase employment opportunity or moderate a decline of labor's relative share. For alleviating the unfavorable effects of non-adapted borrowed technology, we should put emphasis on the importance of the choice of industry.

REFERENCES


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41 The Ministry of International Trade and Industry (ed.) (13), p. 55. This does not deny that the growth of the Tanaka Ironworks owed very much to technical assistance from the government and the demands from military factories.

42 A lack of scientific knowledge and a deficiency of funds in LDCs cannot explain the adoption of capital-intensive methods of multinational firms, because these firms have both scientific knowledge and funds. Technology contains two elements: technology embodied in equipment and experience or skill necessary for its operation. Technicians dispatched to LDCs should be familiar with the equipment installed there, if a failure in operation is to be avoided, or if the operation is to be started successfully as soon as possible. From this it follows that technology exporting countries tend to determine the capital intensity of production methods.


