

## THE FEATURES AND THE DEVELOPMENT STRATEGIES OF GERMAN INDUSTRIAL TECHNOLOGY FROM THE 19TH CENTURY TO THE BEGINNING OF THE 20TH CENTURY

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*Germany took her own specific features and development strategies of industrial technology as compared with other European countries in the 19th century. They can be an important variable in explaining the structural change of the European economy in the 19th century. Also, they are not only showing the technological strategies and risk avoidance strategies of underdeveloped nations whose capital markets are not yet developed, but also offering long-term technological investment direction to late runners in the international market.*

### 1. INTRODUCTION

Though Germany was still an underdeveloped country until the 18th century, she gained the strongest competitiveness in industrial technology in the European economies by the beginning of the 20th century. So, it can be said that it is very important to study German industrial technology in the 19th century for the research of the change mechanism of European economies of those days and the industrial policy of underdeveloped countries.

Nevertheless, the fact is that in Korea as well as in the U.S.A. and U.K., there have been few studies on Germany's industrial technology. Of course, up to now, many researchers have been proceeding with studies focusing on the relative decline of British economy<sup>1</sup>, and pointed out Germany's advantage in industrial

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<sup>1</sup> About the stagnation of U.K.'s economy, there was a controversy between A. E. Musson and A. Levis. D. J. Coppock, and an appropriate criticism of D. N. McCloskey. Musson(1963), p. 531. Coppock(1964), pp. 391-393. Musson(1964), pp. 397, 400-401. McCloskey(1970), pp. 446-459.

technology.<sup>2)</sup> Nonetheless, except the studies undertaken within Germany on Germany's pure technology,<sup>3)</sup> there was not much research on Germany's industrial technology from a German standpoint.

In this context, this paper is pointing out a few features and the development strategies of German industrial technology in the 19th century, which brought out the strongest level of industrial competitiveness to Germany. By doing so, this paper could provide a view for the study on the European economies, especially the economies of the U.K. and Germany, in the latter part of the 19th century which still remain a hot issue, and also show some implications for the technological strategies of underdeveloped nations.

In section II, I analyse the serial condition and posteriority of German industrial technology and in section III, the cross-section condition and resources problem are discussed. In section IV and V, I extend analysis to market problem, and the problem of risk and efficiency of German technology investment respectively. In section VI, I address the summary and some implications of this study as a conclusion.

## II. TIME-SERIAL CONDITION AND TECHNOLOGICAL TRANSFORMATION

In the 19th century Germany had the time-serial condition of one of the late starters in industrialization. The most serious problem of which was technology inferiority. So Germany also introduced technology like other backward countries from the U.K. and any other developed countries, but there is a great difference in that she transformed such introduced technology into industrial technology for mass production. This first feature of Germany's industrial technology, namely, transformation of the introduced technology into industrial one of mass production in major industries, was a technological strategy for Germany as an industrially backward country to get over the time-serial condition and maximize efficiency per unit cost of technology.

First, such a feature of German technology is conspicuous in steel industry, which is one of the most significant industry in the 1870 to 1880. She secured the mass production system and an advantage in the steel industry by introducing the Thomas method, which was the most advanced technology at that time, into

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<sup>2)</sup> It doesn't mean that all the industrial technologies of the U.K. were backward or British enterprises showed a conservative tendency in technological development. For example, as H. J. Habakkuk, S. B. Saul and C. Wilson pointed out, the U.K. had a good lead in open-hearth steel and shipbuilding technologies and British enterprises played an active and creative part in the field of engineering technology and technology of miscellaneous sectors like soap, bicycles until the beginning of the 20th century. Habakkuk(1962), pp. 212-220. Saul(1960), p. 28. Wilson(1965), pp. 183-198.

<sup>3)</sup> Beck(1895). Beck(1897). Beck(1903). Bäumler(1963). Trimm(1972). Stichweh(1984). Radkau(1989).

her steel industry first although major inventions for the steel industry were made in the U.K. and France.<sup>47</sup> As a matter of fact, then-German steel industry was able to adopt the Thomas method promptly because Germany could secure raw ore agreeable to this method and, unlike the U.K., had not still many steel-making furnaces relatively.<sup>48</sup> Above all, however, the introduction of the Thomas steel-making method was triggered by the first feature of German technology, namely, transformation of the introduced technology into the mass production technology. This is well reflected in the data of then-German steel manufacturers on technology switch-over costs and profit/loss from mass production.<sup>49</sup>

Thanks to increase in productivity and mass production by these technology transformations, Germany was able to overcome cost disadvantages and start to develop its heavy industry in earnest. As the German steel industry had used puddling furnace and puddle method before the Great Depression, which needed a long duration of manufacturing process and a large quantity of work force, it had had cost-push factors and supply bottleneck, and low strength of wrought iron had impeded the development of the machine industry. But Germany was able to achieve mass production of basic pig-iron and steel by Thomas method and promote the development of related industries.

The transformation of the introduced technology into mass production technology in Germany emerged in almost all the industries that were expanding as a growing industry. Though rolling technology for the metallurgical industry, which was called 'the innovation of industrial technology', appeared in the beginning of the 19th century, the first industrial rolling mill manufacturing large-sized girder and rail wheel was made in Germany in the 1850s. Also, the three-high mill, which was invented by O. E. Karlsund(Sweden) in 1856, was extensively adopted in Germany than the U.K. or Sweden.<sup>50</sup> In the U.K. where G. Bedson developed a innovative continuous wire-rod rolling mill in 1862, the continuous rolling method was ignored substantially, while Germany utilized positively this technology as an industrial technology.<sup>51</sup> It was also Germany that transformed Nasmyth's

<sup>47</sup> In 1890, P. C. Gilchrist pointed out such a feature of Germany and criticized British manufacturers. *Proceedings of the Cleveland Institution of Engineers*, Middlesbrough, 1890-1891, p. 131.

<sup>48</sup> In this point, excessive 'related costs' of adjustments to subsequent change from the U.K.'s priority in the industrial revolution, i.e., the comparative disadvantage of priority in technical innovation and economic development can be pointed out. However, this cannot be a main reason if then-industrial demand, raw materials, etc. are taken into account. As to the comparative disadvantage of priority in U.K., see follows. Frankel(1955), pp. 296-319. Salter(1960). Kindelberger(1961), pp. 281-297. Landes(1991), pp. 334-337, 353. Habakkuk(1962). Musson(1963), pp. 529-533. Yamazaki(1980), p. 78.

<sup>49</sup> Wengenroth(1994), pp. 158-159, 193.

<sup>50</sup> Институт истории естествознания и техники Академии наук СССР (1990, Korean ed.), p. 309.

<sup>51</sup> Landes(1965), p. 493.

<sup>52</sup> Levine(1967), PP. 39-42. British Iron Trade Association(1896), p. 13.

steam hammer, which K. Marx in his *Das Kapital* took as a definite example of the technical progress in the machine industry, into steam hammer of 50 to 100 tons in the 1870s.<sup>10</sup> Even though Beau de Rochas's four-stroke cycle made crucial conceptual contribution in internal combustion engines, which changed mechanical system basically in the 19th century, in 1862, it was German who put this principle to effective use and produced the first practical gas engine by which Germany swept the world engine market within a few years.<sup>11</sup>

The Solvay alkalis method developed in Belgium in the 1870s brought on an innovation in the production of soda which was the most important chemical industry. The Solvay method overcame the limitation of productive process in the existing ammonia soda process<sup>12</sup> and reduced the production cost by 20% compared with that by the Leblanc technique from the beginning of introduction,<sup>13</sup> and it also caused a continuous, substantial drop in production cost. While the U.K. and other European countries were using the traditional process, i.e. Leblanc method developed in France until the 1880s, Germany replaced it with an improved Solvay method to convert into a mass production system by which a 70% of the total output of soda was already produced in 1887. Coping with the Solvay method, the U.K. also succeeded in extracting chlorine from the by-product and reduced the coal consumption by 1/3 or more during the period from 1872 to 1882, but, after all, Germany secured an advantage in the alkalis industry by introducing the electrolytic method of preparing chlorine and caustics in the 1890s.<sup>14</sup>

In addition, in the field of coal-tar industry which the U.K. enjoyed an advantageous position in the basic inventions and industry itself until 1885, the U.K. applied for 86 cases of industrial patents, whilst Germany applied for 948 cases of patents for related industries from 1886 to 1900.<sup>15</sup> This means that Germany was very eager in converting the inchoate technology to the industrial technology of mass production.

The electric industry which was the last industry in the 19th century and

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<sup>10</sup> Институт истории естествознания и техники Академии наук СССР (1990, Korean ed.), p. 312.

<sup>11</sup> Field(1958), p. 159.

<sup>12</sup> The Leblanc technique for the production of sodium carbonate had a weak point, i.e. waste of sulphur and calcium, and mass consumption of coal. The ammonia soda process developed in 1811 also had a disadvantage in cost as it was impossible to regain ammonia which was very expensive at that time.

<sup>13</sup> Thanks to the Solvay method, the price of soda dropped from 13 pounds per ton in 1863 down to 4 pounds per ton accounting for 30% of the foregoing price in 1902. Saul(1979), p. 24.

<sup>14</sup> While the ratio of use of electrolytic method for the production of chlorine in Germany rose to the level of 65% in the first half of 1900, it remained at just the level of 10% in the U.K.

<sup>15</sup> S. F. Cotgrove, *Technical Education and Social Change*, 1968, p. 20. re-cited from Landes(1991), pp. 352-353.

oriented the direction of industrial development for the 20th century also began in the U.K., but it was in Germany that a variety of innovation were carried out frequently and competitively in industry directly.

### III. CROSS-SECTION CONDITION AND BACKWARD LINKAGE TECHNOLOGY

The second feature of the German industrial technology in the 19th century can be traced from the cross-section condition that Germany suffered a shortage of coal and iron which were major resources for industrialization compared with the U.K.<sup>16</sup> At that time, coal was an essential raw material for steel industry, electrical power generation, metallurgical industry, and chemical industry, etc. and iron was a resource that determined an industrial advantage. But, as seen in Figure 1, compared with the U.K., Germany suffered an absolute shortage of those two resources, resulting in bottleneck of the industrial development.

As a result, Germany was forced to depend on the import of resources such as pitch, tar, and anthracene which was the raw material of alizarine dyes from the U.K. while developing the chemical industry substantially<sup>17</sup>. In addition, despite the monopolistic position in coal-tar derivatives and the overtaking in the output of steel after the 1890s, Germany should import tar and pig iron continuously from the U.K.<sup>18</sup>

Such difference in natural resources enabled the U.K. to continue to develop the technology for the mining industry, while Germany accomplished the second feature of the German industrial technology and technological strategy which is the technological development in the resource-saving industry and in the industry based on the development of artificial new power source and new resources from the early stage.

In the 1870s when the Great Depression began, the U.K. mechanized the underground coal mining operation including ventilation of coal mine, towing of

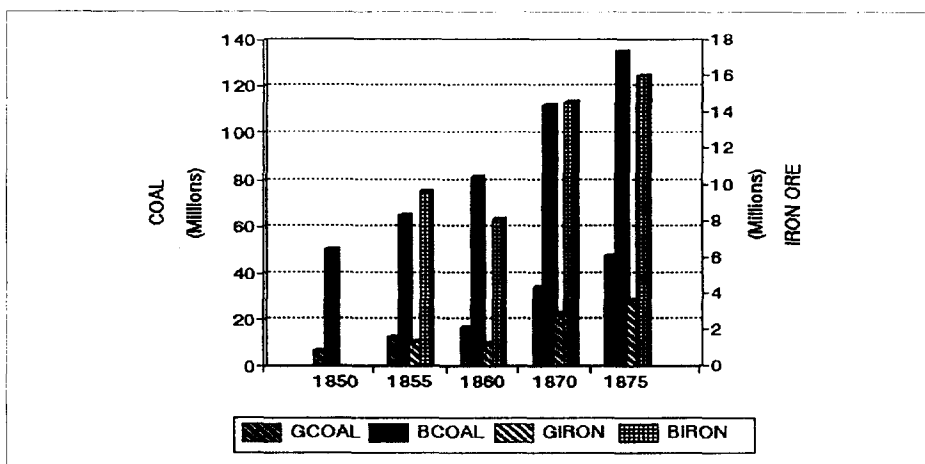
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<sup>16</sup> For the purpose of emphasizing the relative sluggishness of the U.K. and the advantage of Germany, some arguments pointed out that Germany had abundant natural resources. However, these arguments stemmed from the relative advantage in nonferrous metals such as copper, lead, etc. and the overestimation of the quantity of natural resources resulting from the annexation of Alsace-Lorraine. In fact, looking into the research data of 1928 which enlighten a statistical comparison of individual countries' estimated amount of resource reserves, the estimated amount of iron ore in Germany was 4,160 million tons, compared with 94,324 million tons, 12,250 million tons, 12,170 million tons in the U.S.A., France, and the U.K. respectively. Burnham and Hoskins(1943), p. 106.

<sup>17</sup> U.K., *Parliamentary Papers*, 1901, LXXX, 2, 'Report on Chemical Institution in Germany and the Growth and Present Condition of the German Chemical Industries', pp. 42, 68.

<sup>18</sup> U.K., *Parliamentary Papers*, 1901, LXXX, 2, 'Report on Chemical Institution in Germany and the Growth and Present Condition of the German Chemical Industries', pp. 42, 68. Carr and Taplin (1962), pp. 164, 167.

[Figure 1] Output of Coal and Iron Ore (U.K. and Germany)



Sources : Mitchell(1981), pp. 381-383, 385, 408-409.

Notes : 1) GCOAL: output of coal in Germany. BCOAL: output of coal in U.K. GIRON: output of iron ore in Germany. BIRON: output of iron ore in U.K. 2) left Y axis: output of coal, million tons. right Y axis: output of iron ore, million tons. 3) coal output is total output of hard and brown coal. 4) From 1871 Germany includes Alsace-Lorraine. 5) As there are no data for U.K.'s iron ore before 1854, the comparison of both countries is impossible in 1850.

ore, transport within mining pits, and underground drainage and used stronger and safer gun cotton in their mines. Furthermore, she made the drill-type coal-cutter in the 1870s and electric motor-mounted disc and rod coal-cutter by 1887.<sup>19)</sup> The fact that A. B. Nobel of Sweden obtained a patent for dynamite in the U.K. shows well that then-U.K. was concentrating its efforts on the development of mining technology. As a result, the productivity in the mining industries of both countries differed.

Of course, Germany made its great effort in the increase of productivity of the resource industry to break through the shortage of natural resources, while mines of the U.K. extended to the inferior ones<sup>20)</sup>, with the result that at the end of the 19th century the difference in both countries' productivity in the mining industry was narrowed down. But a fundamental difference in the amount of na-

<sup>19)</sup> Институт истории естествознания и техники Академии наук СССР (1990, Korean ed.), pp. 283-287.

<sup>20)</sup> Sandberg(1981), p. 117.

**[Table 1]** Productivity in the Mining Industries (production per man per year, tons)

coal mining					
year	1874-78	1879-83	1884-88	1889-93	1894-98
Germany	209	257	269	257	262
U.K.	270	319	319	282	287
iron ore mining					
year	1875	1880	1885	1890	1900
Germany	160	220	250	300	450
U.K.	570	460	N.A	400	N.A

Sources: Burnham and Hoskins(1943), p. 118. Taylor(1968), p. 46.

Notes: 1) The productivity in the coal mining industry is an average of the 5-year periods. 2) The figure representing the productivity of labor in the U.K.'s iron ore mining industry in 1875 was quoted from Cleveland, while the figures for other years were calculated by averaging the Cleveland, West Coast Hematite, and Coal Measures.

tural resources and the U.K.'s continued development of resource industry combined to cause Germany to be placed in an inferior position in productivity of coal and iron ore mining industries, as Table 1 illustrates.

On the other hand, to overcome a shortage of resources such as coal and iron ore, Germany focused its efforts on developing an industry based on the artificial new power source and new resource as well as resource-saving, technology-intensive industry, and the development of technology was oriented and promoted in such a direction from the early stage. As a result, Germany took a lead in the optical industry, one of the resource-saving, technology-intensive industries and sought to develop chemical technologies for the new resource and electrical technologies for new power source.

First of all, Germany developed almost all the optical technologies relating to the development of achromatic telescope, manufacture of objective lens for telescope, lens polishing, lens surface inspection technique, optical glass scattering measurement, etc.<sup>21</sup> and succeeded in putting these optical technologies to practical use for industrialization from the early stage.<sup>22</sup> Consequently, in terms of the number of optical instrument manufacturing firms, there were 1-2 international

<sup>21</sup> The world-wide optical instrument boom in the 1830s was occasioned by the development of optical instrument by Germany.

<sup>22</sup> Also the optical glass manufacturing method was completed in Germany in 1881. Dong-A Publishing & Printing Co(1982), p. 190.

firms in the U.K., France, and Austria respectively, while Germany already had 5-6 big international enterprises such as Fraunhofer, Carl Zeiss, etc. by the latter part of the 19th century and succeeded in the globalization of its optical instrument industry. In the 1870s, Carl Zeiss accomplished a unique technological level in the optical industry, which prompted Germany to dominate the world market in this field.

The major technologies in the chemical industry were also industrialized in Germany. The definition of 'chemical engineering' itself was invented also in Germany at the end of the 18th century.<sup>23)</sup> Since using sulphuric acid, which was regarded as a yardstick for technological, industrial strength of each country after the end of the 19th century, in the dyeing industry for the first time in the world, Germany already possessed more than 30 enterprises dealing with enriched sulphuric acid in Sachsen province by the end of the 18th century.<sup>24)</sup> In 1840, German enterprises invented mineral sulphuric acid by burning chalcopryrite, zinc sulfide ore, and zinc blende in Sachsen province, resulting in the concurrent development of metallurgical industry and chemical industry,<sup>25)</sup> but U.K.'s annual use of pyrite still remained a negligible amount at that time.<sup>26)</sup> As a result, in the field of sulphuric acid, by the mid-1840s Germany became a net exporter, even though the output in the U.K. was almost twice as much as that in Germany until the 1890s because of low demand from late industrialization in Germany<sup>27)</sup>, and moving into the 1900s, Germany had gained quickly an advantage over U.K. and other European countries.

In addition, further to the commencement of commercial production of pin plate, Germany succeeded in separating pulverized aluminium using vaporized calcium in 1827 for the first time in the world.<sup>28)</sup> Furthermore, Germany opened a new horizon for the potassium industry which was a derivative field from both the mining and chemical industries from the 1870s.<sup>29)</sup>

By its perfect transmissibility and flexibility of conversion into other energy, electric power changed the consumption patterns and production methods drastically after the 1890s. While the U.K. paid its major concern to power plant to supply electric light for each province by *Electric Lightening Act*, Germany accomplished the decisive breakthrough in electrical technology by constructing a

<sup>23)</sup> Институт истории естествознания и техники Академии наук СССР (1990, Korean ed.), p. 320.

<sup>24)</sup> Ibid., pp. 327-328.

<sup>25)</sup> Ibid., pp. 305-307, 331.

<sup>26)</sup> Haber(1958), p. 103.

<sup>27)</sup> The abundance of cheap raw materials and economies of scale gave U.K. a tremendous comparative advantages. Landes(1965), pp. 343, 415.

<sup>28)</sup> Институт истории естествознания и техники Академии наук СССР (1990, Korean ed.) pp. 302, 305.

<sup>29)</sup> Ibid., pp. 332-333.



large-sized high voltage electric power plant to deliver 225 kW over 179 km at 30,000 volts from Lauffen to Frankfurt-am-Main in 1891<sup>30)</sup>. From this time onward, the electric industry of Germany began to grow rapidly by its efficiency and economic profitability.<sup>31)</sup> Because, unlike the U.K., Germany pursued aggressively the electrification of manufacturing plants to overcome a resource shortage,<sup>32)</sup> and also the electricity demand related to the new industries was growing rapidly in Germany.<sup>33)</sup>

Such an intensive effort to develop the resource-saving, technology-intensive industry, new resource, and new power sources molded a feature of the German industrial technology which is the development of backward linkage technology, unlike the U.K. that was developing the technology of forward linkage industry such as the munitions industry, shipbuilding industry, heavy machine industry, etc.

#### IV. MARKET DIFFERENTIATION<sup>34)</sup> AND NEW INDUSTRIAL TECHNOLOGY

The third feature of the German industrial technology became evident during the latter part of the Great Depression at the end of the 19th century.

In the latter part of the 19th century, the U.K. was dominating world market in light industries, open-hearth steel related industry, and large-sized assembly industries thanks to its broad raw material markets and commodity markets all over the British Empire. This situation encouraged Germany as a late starter to make inroads into markets differentiated from the market of the U.K., to expand new markets.<sup>35)</sup>

Consequently, in the latter part of the 19th century, Germany pursued technological development in new industries such as new steel, organic chemistry, electro-chemistry and electro-metallurgy, and electrical equipments. Like this, the intensive effort on and success in technological development in the field of new

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<sup>30)</sup> G. Olphe-Galliard, *Le force motrice au point de vue économique et sociale*, Paris, 1915, p. 104, re-cited from Landes(1965), p. 513. Fox and Guagnini(1994), p. 83.

<sup>31)</sup> The U.S.A.'s technology also played an important role in Germany's technological development for the electric industry. Pollard(1989), p. 160.

<sup>32)</sup> In case of Germany, the consumption of electric power was 1 giga Watt hours in 1900, while no more than 0.4 giga Watt hours in case of the U.K. during the same year. The difference became wider thereafter. Mitchell(1981), pp. 500-501.

<sup>33)</sup> Of course, there was also the rapid increase in demand for electric light.

<sup>34)</sup> According to general concept, here, this means product differentiation.

<sup>35)</sup> Up to now, Many researches have allowed much space for the U.K.'s comparative disadvantages of priority with little interest in Germany's or other countries' disadvantages of posteriority. However, such a viewpoint is given in the place of the U.K. If reviewed in the place of other countries, the converse holds true naturally.

and rapidly growing industries differentiated from the existing market of the U.K. was the third feature and also development strategy of the German industrial technology. Such development of new industrial technologies in Germany were the prerequisites for clearing technological dependency on the U.K., but at the same time demanded that German investors should have long-term future-profit oriented and long-term technological development oriented mind. As a result, while British entrepreneurs put the current embodied technology before anything and regarded the technology as an exogenous variable that was obtained on the production site, those of Germany considered the technology as a long-term endogenous variable that was a capital to be developed on a long-term basis. This was the basic difference between both countries' technological strategies in the 19th century.

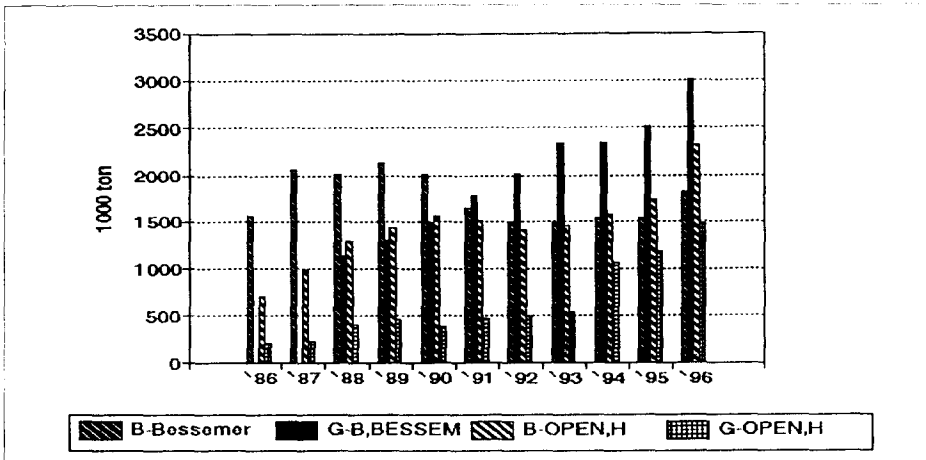
The foregoing efforts of Germany are definitely shown in that Germany, as a late runner in the steel industry, concentrated its energies upon basic bessemer steel in order to avoid friction with the U.K. in the steel market. In consequence, while the U.K. came to possess a dominant productive capacity in the open-hearth steel sector, Germany secured a dominant position in the basic bessemer steel sector as seen in Figure 2. By specializing the basic bessemer steel differentiated from the British market, Germany was able to dominate the world steel market by the beginning of the 1890s.

The organic chemistry also was simultaneously initiated in the U.K., Germany, and France at the early stage, but after the U.K. and Germany developed alizarin, the world first artificial dyes, in 1869, Germany embarked upon a new era assuring of its productive advantage. The dying industry of Germany, which was small scale in the 1860s, was able to supply a half of the world requirements in the 1870s and more than 90 percent by the end of the 19th century respectively. As a result, major firms of European countries came to depend on German enterprises such as Badische Anilin, Höchst, and AGFA in the end of the 19th century.

Electro-deposition technology for refinement of copper, which was called an epoch-making industry as a new industry in the applied electro-chemistry sector because of its high value-added and high possibility of application to the related industries, was put to practical production process in Germany in 1878 for the first time in the world. The copper refinement was an epoch-making improvement correcting the weak point of iron, and at that time the demand for it was growing rapidly due to the development of electric industry.

The German electrical equipment industry grew synergically with the second technological feature of Germany which was eager to overcome energy resource and raw material shortage. Thanks to the development of heavy electro-chemistry and electro-metallurgy industries and diffusion of electric motor in the 80s to 90s, the electrical equipment industry was nurtured as the most spotlighted new industry. Especially, Germany concentrated upon the development of electrical equip-

**[Figure 2]** Production of Steel by Process (U.K. and Germany: thousand tons)



Sources : Beck(1903), pp. 1057, 1059. Kaiserliches Statistisches Amt, *The Statistisches Jahrbuch für das Deutsche Reich*. 1907. Carr and Taplin(1962), pp. 126, 173.

Notes : 1) B-Bessemer: British Bessemer steel(not only basic Bessemer steel but all). G-B,BESSEM: German basic Bessemer steel. B-OPEN,H: British open-hearth steel. G-OPEN,H: German open hearth steel. 2) The data of German basic Bessemer steel in 1886, 1887 are not available.

ment technology in the 1890s for encouraging manufacturing factories to use electricity in an effort to overcome a resource shortage as well as for the purpose of market differentiation from the U.K.

At last Germany took a lead in the electrical equipment technology during the 1890s further to the technological advantage in the organic chemistry in the 1880s in Europe. From the end of the 19th century, the advantage in these two technologies ensured a competitive advantage in industry and export. As a result, at the beginning of the 20th century, Germany, basing on the fields of chemical nitrogen, dyestuffs, and rayon yarn, enjoyed the dominant position as the largest chemical product producing country<sup>30)</sup> and became the largest electrical equipment exporting country in Europe<sup>31)</sup>. This means that German industrial tech-

<sup>30)</sup> In 1913, Germany produced chemical products accounting for 24% of the world output, while the U.K. and France recorded 11.0% and 8.5% respectively. Richardson(1968). p. 278.

<sup>31)</sup> According to the U.K.'s import of electrical machinery by countries in 1907, the largest supplier was Germany( £ 278,000). On the other hand, the U.K.'s export of electrical machinery to the whole Europe amounted no more than £ 89,000. Byatt(1968). p. 259.

nology proceeded to take an independent development stage.

#### V. CONCENTRATION AND SPECIALIZATION: CAPITAL MARKET AND RISK

The most critical obstacles that Germany encountered in the course of developing industrial technology were the instability of its capital market and a shortage of commodity market due to posteriority, and long duration of investment and high risk resulting from the development of backward linkage industry technology and new industry technology which constitute the features of the German industrial technology. Especially, risk resulting from long duration for returns and uncertainty of technological investment in the backward linkage industry and new industry was a great obstruction to Germany whose capital market was unstable.

Up to now it has been explained that such a shortage of capital caused by instability of the capital market in Germany had been solved by a close relationship between large scale enterprises and financial institutions.<sup>87</sup> As a matter of fact, German financial institutions organized and concentrated industrial finance better than those of the U.K.<sup>89</sup> However, although the German heavy industry and electro-technical industry were in a interrelationship with the financial institution, the engineering industry and chemical industry was not in so close a relationship with the financial institution.<sup>100</sup>

The fourth feature of the German industrial technology is related to Germany's strategy of technological investment aimed at solving the above-stated problem. Germany resolved this problem by means of an approach in the place of the then-Germany, i.e. a backward country. The key points of this solution were an intensified technological investment by stages and industries, and another intensified investment in the specific manufacturing industry which was creating a newly growing demand together with a differentiation from the British market even in the same industry by stages. This was the fourth feature of the German industrial technology.

First, Germany intensified technological investment in vital industries by periods, i.e. pre-Great Depression, former part in the 1870s to 1880s, latter part in the 1880s, and the 1890s. Furthermore, Germany selected, from the industry concentrated by periods, some manufacturing sectors with the greatest possibility of creating a new demand by a cross-section and made an intensive technological investment in such sectors. By doing so, Germany was able to resolve the capital

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<sup>88</sup> Gerschenkron(1962), p. 18. Landes(1991), pp. 349-350. Sandberg(1982), pp. 675-698. Chandler(1990), chaps. 10-12. Tilly(1990), pp. 107-110. Kieseewetter(1991), p. 289.

<sup>89</sup> Davis(1966), pp. 255-272. McCloskey(1970), p. 446.

<sup>100</sup> Feldenkirchen(1991), pp. 116-135.

shortage, to make push for the maximization of efficiency in technological development, and to reduce the risk of technological investment. At the same time, these contributed to the solution of the issue of market differentiation from the British market.

For example, Germany concentrated its capital and technological investments in the optical industry during the pre-Great Depression, the steel industry during the Great Depression in the 1870s to 1880s, the organic chemistry industry during the 1880s, and the electric power and electric appliance industry during the 1890s respectively. In addition, as those vital target industries were overlapped with each other in the 1880s, Germany specialized some manufacturing sectors even in the same industry and concentrated technological investment in such sectors. Namely, in the 1880s, specialization was made for basic bessemer steel within the steel industry and dyes, drugs, and photographic chemicals within the chemical industry respectively. Germany attempted to generalize the chemical industry for the first time in the world by nurturing a large number of chemists already in the 1880s<sup>11</sup>, but in fact Germany pursued the specialization of specific sectors in the chemical industry through an intensive technology investment of industry-university linking system in specific sectors. Especially, the specialization within the chemical industry made Germany secure a technological advantage over the U.K.<sup>12</sup> and France thereafter. By doing so, Germany was able to concentrate its insufficient capital effectively and achieve a technological advantage and market control in steel and chemical industry in the 19th century.<sup>13</sup>

By concentrating its capital and deconcentrating investment risks by periods, industries and by specific manufacturing sectors within same industry, Germany as a backward country was able to achieve its strategy of the development of industrial technology and to complete an industrial structure with a technological advantage gradually in the optical industry, steel and nonferrous metal industries,

<sup>11</sup> Sandberg(1981), pp. 113-114.

<sup>12</sup> In case of the U.K. also, the growth rate of chemical section surpassed any other sections except the public sector during the period from 1900 to 1911.

<sup>13</sup> By quoting that shares of the chemical industry in employment and export were 2% and 4% even in the last year before the war respectively, Pollard(1989), p. 162 pointed out that the German chemical industry have been overestimated. However, this argument ignored some problems in statistics and did not understand the features of the German industrial technology i.e. specialization of specific sections in chemical industry and chemical industry itself. As explained above, Germany concentrated her effort upon some specific sections, not upon the entire chemical industry, and accordingly the contributions of the chemical industry to the fields of employment and export were low. Second, as the chemical industry takes on a heavy equipment industry character, the comparison of employee itself is meaningless. This is well shown from that while in 1862 400,000 employees were employed in the textile industry in England and Wales, the Leblanc factory which was the most brisk factory at that time employed merely 10,000 persons-the number of direct labor was no more than 2,000-(Landes(1965), p. 498). Finally, as the chemical industry takes on a input material producing industry character, the statistics of export do not have a significant meaning either.

chemical industry, and electric appliance industry during the period from the end of the 19th century through the beginning of the 20th century.<sup>11)</sup> As a result, in spite of its late start for industrialization, Germany was able to have its own technology linking system together with strong technological competitiveness.

## VI. CONCLUSION

Germany took her own specific features and development strategies of industrial technology as compared with other European countries in the 19th century.

The first feature and strategy is the maximization of efficiency in its industrial technology through transforming the technology developed in the U.K., France, etc. into the industrial technology of mass-production in its domestic industrial sectors. This feature emerged from the time-serial condition Germany was facing as a backward country. The second feature is that Germany concentrated its effort upon the development of artificial new power source, new-resources using industries, and resource-saving, technology-intensive industries. This second feature derived from the cross-section condition, i.e. a shortage of coal and iron ore that were a major resource for industrialization. As a result, Germany developed its own unique backward linkage industry technology. The third feature is the concentration upon and success in the development of technologies of some specific new industries which created a rapidly growing demand and were differentiated from the British market. The fourth feature, which was related to German fourth strategy of technology development, is that Germany as a backward country resolved the capital shortage and the risk resulting from long duration for returns and uncertainty by concentrating its technological investment by periods and industries.

Especially, the second and third features manifest Germany's technological strategy in the 19th century for overcoming a resource shortage, clearing technological dependency on the U.K., and creating a differentiated market. Based on such a technological strategy, Germany furthered another strategy of technology development regarding technology as an endogenous variable and capital to be developed on a long-term basis.

The features and strategies of the German industrial technology can be an important variable in explaining the structural change of the European economy in the 19th century. Also, they are not only showing the technological strategies and risk avoidance strategies of underdeveloped nations whose capital markets are not yet developed, but also offering long-term technological investment direction to late runners in international market. The future task of this paper is to

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<sup>11</sup> Irrespective of its dominant position in the European market, Germany began to fall behind the U.S.A. in the auto and electrical equipment industry, etc. This was caused by Germany's relative failure compared with U.S.A. just like the case of the U.K. and Germany in the 19th century.

find German technology function. But as there are still some limitations on the availability of required data, it is unavoidable to set aside this task for the time being.

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