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ECONOMICS 303Y1

The Economic History of Modern Europe to1914

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Lecture Topic No. 24:

V. THE RAPID INDUSTRIALIZATION OF GERMANY, 1815 - 1914

F. GERMAN INDUSTRIALIZATION, 1850 - 1914

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1. Introduction: The Beginnings or 'Take-Off' of German Industrialization

a) **During the later 18th and early 19th centuries**:

i) **certainly many regions of Germany experienced some significant economic development,** during the later 18th and early 19th centuries.

- especially in the Berlin, Hamburg, Cologne [Köln], Dresden, and Frankfurt-am-Main regions.
- Hamburg and the other former Hanse towns (Bremen and Lübeck) remained important for commerce

ii) **German towns of the old Hanseatic League:**

(1) the following German commercial towns had been the most important components of the former Hanseatic League, which had dominated northern European commerce from the later 13th to 16th centuries:

- the German Baltic towns, led by Hamburg and Lübeck,
- and the German Rhenish towns, led by Cologne, another major former Hanseatic town.

(2) their subsequent relative decline in international commerce did not mean that they became economically unimportant.

(3) Hamburg in particular remained one of Europe's leading shipping and commercial centres

iii) **Trebilcock: notes a long, slow, but important period of economic development, 1780-1850;** and this you can read for yourselves, of course.[1]

b) **But that economic growth was generally slow and quite uneven up to the 1850s**:

(1) in agriculture, industry, banking, foreign trade, etc.;

(2) and thus Germany was well behind France and the Low Countries, not to mention Britain.

c) **From the 1850s, there is much more rapid growth and discernible industrialization, so that we might talk of a 'take-off'**, involving the following factors already discussed:

i) **market:** unification of the domestic market through the Zollverein.

ii) **transport:** establishment of the chief railway lines to link up Germany's natural resources (especially coal and iron), major towns, and seaports; and also parallel development of canals.

iii) **Agrarian reform:** 1850 Emancipation Law marked new and more rapid phase of land reform (especially benefiting the East German Junkers).

iv) **Banking:** Establishment of the first great investment banks in the 1850s.

d) **Textiles**: marked initial phase of modern industrialization

i) **Cottons:** In Germany, as elsewhere, the cotton industry was the first industry to mechanize, in adopting a modern factory system of powered production, as elsewhere.

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[1] Clive Trebilcock, *The Industrialization of the Continental Powers, 1780 - 1914* (London and New York: Longman, 1981), pp. 22-37.

ii) **But the German cotton industry could hardly compete with the British cotton industry:** in lacking the British access to American cotton, and lacking access to those large overseas markets that Britain possessed.

iii) **Despite the very impressive growth of the German cotton industry,**

(1) it never really competed with the British;

(2) and in 1914, it had only 20% of the physical capacity of the British cotton industry.

e) **Metallurgy: the Coal, Iron, and Steel Industries:**

i) **These proved to be the true spearheads of German industrialization,** as was true almost everywhere from mid-19th century.

ii) **1850s**: **discovery of vast quantities of excellent quality coking coal,** in the Ruhr River valley and the Rhineland-Westphalia.

(1) both the discovery and the exploitation of these coal fields was result of railway surveying and construction.

(2) Previously Germany's known and available coal deposits were of mediocre quality;

- in contrast, these Ruhr-Rhineland deposits were not only so very excellent in coking quality,
- but also so extensive that they accounted for 50% of western Europe's total coal supplies.

(3) That coal made this Rhineland-Ruhr region the true industrial heartland of modern Germany, indeed of western Europe, up to the present day.

iii) **Legal Reforms of 1851**: the Prussian government liberalized mining laws, promoting coal mining (controlled the Rhineland region).

2. <u>**Chief Features of German Industrialization, 1870 - 1914**</u>

a) **This period overall is the one during which German industrialization rapidly advances,** to overtake not only France and Belgium, but also Great Britain in many key fields: in steel, electrical, chemicals industries.

b) **Major Features of German industrialization in post-1870 era**:

i) **Very close links between science and industry, with German scientific leadership in many fields**: especially electrical and chemical.

ii) **Tariffs: the Return to protectionism in both industry and agriculture**: from 1879, a high tariff structure was restored and then raised even further.

iii) **Leadership role of the investment banks in heavy industry**:

iv) **Industrial amalgamations and cartels**: from both industrial protectionism and investment banks.

v) **This era, however, is usually divided into two,** in surveying trends in European economic development: 1873-1896 and 1896-1914.

c) **The Period 1873 - 1896**: the 'Great Depression' era. Was it also an era of depression for Germany?

i) **The year 1873 did mark the beginning of an international financial crisis,** with some slumps in international trade that can be seen reflected in the export statistics for Britain and France, especially 1875 - 1885 [see Table 8, in the appendix: landscape format]

ii) **Furthermore, the entire period was generally deflationary:** almost universally true.

iii) **Foreign Trade:** Germany's exports continued to rise, however, until the mid 1880s, when they reached a plateau that lasted a decade, until the mid 1890s, when a new and much more powerful export boom ensued.

iv) **Agriculture:**

(1) In the 1870s and again in the 1880s, both German agriculture and some German industries suffered a fairly severe slump, so that

(2) both agriculture (faced with a flood of cheap grain imports) and heavy industry now clamoured for protection, which they soon received, in increased tariffs

v) **Tariffs:** as just noted, the German imperial government, though Prussian based, succumbed to this pressure and jettisoned its long-held free trade policies to restore protectionism, beginning with high tariffs in 1879 for grain, iron, steel products.

vi) **But the second half of this so-called 'Great Depression' period, from 1882 to 1896,** witnessed Germany's fastest industrial growth rate so far in the 19th century: at 4.5% per annum

vii) **The table on comparative industrial growth rates:** shows that Germany experienced continuous growth in industrial output over the entire period 1870 to 1914, with much faster growth rates than the U.K. or France (and surpassed only by the U.S.).

Indices of Industrial Output*: in the United Kingdom, France, Germany, and the United States in quinquennial means, 1860-4 to 1910-13

Mean of 1870-4 = 100

Period	**United Kingdom**	**France**	**Germany**	**United States**
1860-64	72.6			
1865-69	82.8	95.8	72.6	75.5

Period	United Kingdom	France	Germany	United States
1870-74	100.0	100.0	100.0	100.0
1875-79	105.5	109.5	120.8	111.4
1880-84	123.4	126.6	160.6	170.4
1885-89	129.5	130.3	194.9	214.9
1890-94	144.2	151.5	240.6	266.4
1895-99	167.4	167.8	306.4	314.2
1900-04	181.1	176.1	354.3	445.7
1905-09	201.1	206.2	437.4	570.0
1910-13	219.5	250.2	539.5	674.9

* Excluding construction, but including building materials.

Source: W. Arthur Lewis, *Growth and Fluctuations, 1870 - 1913* (London, 1978), pp. 248-50, 269, 271, 273.

d) **The Period 1896 - 1914 for German Industrialization**:

i) **In terms of international trade and capital investments,** this was a boom period, and also one of renewed inflation lasting until World War I.

ii) **In this period specifically, Germany overtook Britain in steel production:** or rather in certain aspects of steel production.

iii) **more importantly, Germany established world supremacy in two new key industries:** the chemical and electrical industries.

iv) **German industrial amalgamation and cartelisation:** became much more pronounced during this period.

3. <u>**German Mastery in the Steel Industry**</u>

a) **Comments on German coal and iron production**: as prelude to the history of German mastery in the steel industry:

i) **coal:** statistics up to World War I (1914)

(1) note from the statistics on the screen that Germany rapidly overtook France in coal production, producing more than double the French coal output by the 1870s;

(2) but Germany never succeeded in overtaking Britain in aggregate coal production.

Output of Coal in Millions of Metric Tons:

For Selected European Countries, Decennial Means: 1820/9 - 1910/3

Decade	Great Britain	Belgium	France	Germany	Russia
1820-9	20.00	n.a.	1.30	1.40	n.a.
1830-9	25.45	2.75	2.45	2.45	n.a.
1840-9	40.40	4.60	3.95	5.25	n.a
1850-9	59.00	7.70	6.45	11.95	n.a
1860-9	95.50	11.35	11.35	25.90	0.45
1870-9	129.45	14.70	16.20	45.65[a]	1.60
1880-9	163.40	17.95	20.85	71.90[b]	4.35
1890-9	194.15	20.70	28.45	107.05[c]	9.05
1900-9	245.30	24.05	34.70	179.25[d]	20.50
1910-3	275.40	24.80	39.90	247.50	30.20

Germany: proportion of total coal output accounted for by lignite:

a. in 1871 22.4%
b. in 1880 20.5%
c. in 1890 21.4%
d. in 1900 27.0%
e. in 1910 31.3%

1 metric tonne = 1000 kilograms = 2,204.6 lb.

Source: Carlo Cipolla, ed., *Fontana Economic History of Europe*, Vol. IV:2, p. 770.

ii) **German Iron production**:

(1) Germany was not as rich in iron ore as in coal,

(2) and thus the Germans had to import much of their iron ore,

- even after the acquisition of Lorraine from France in 1871 (Franco-Prussian War),
- though they imported considerably less iron than before, of course.

(3) France and Germany: comparisons of industrial production

- From the table on the screen, we can see that as late as 1860, Germany was still behind

France in iron production,

■ but Germany had overtaken France by 1880;

(4) Germany did not, however, overtake Britain until just after 1900.

Decennial Averages of the Output of Pig Iron and Steel in France, Germany, Russia, and the United Kingdom, in millions of metric tons,

1830-9 to 1910-3 (iron) and 1870-9 to 1910-3 (steel)

Index: mean of 1880-9 = 100. 1 metric ton = 1000 kg. = 2,204.6 lb.

Decade	**France**	**Index**	**Germ-any**	**Index**	**Russia**	**Index**	**U.K.**	**Index**
IRON PRODUCTION								
1830-9	0.286	16	0.129	4	0.172	31	0.921	11
1840-9	0.442	25	0.172	5	0.192	35	1.625	20
1850-9	0.731	25	0.334	5	0.243	44	3.150	39
1860-9	1.164	66	0.813	25	0.304	56	4.602	57
1870-9	1.337	75	1.678	52	0.400	73	6.648	81
1880-9	1.772	100	3.217	100	0.547	100	8.040	100
1890-9	2.192	124	5.155	160	1.539	281	8.090	101
1900-9	3.028	171	9.296	289	2.786	509	9.317	116
1910-13	4.664	263	14.836	461	3.870	707	9.792	122
STEEL PRODUCTION								
1870-9	0.260*	52			0.080*	33	0.695	30
1880-9	0.500	100	1.320	100	0.240	100	2.340	100
1890-9	1.015	203	3.985	302	0.930	388	3.760	161
1900-9	2.175	435	9.505	720	2.490	1038	5.565	238
1910-13	4.090	818	16.240	1230	4.200	1750	6.930	296

Decade	France	Index	Germ-any	Index	Russia	Index	U.K.	Index

*1875-9 only.

b) **The German Steel Industry**: slow growth in the early years

i) **as noted, Britain had led the way during the first generation of the Steel Revolution,** during the 1860s and 1870s, in both output and productivity.

ii) **As also noted, most of Germany's own iron ores were phosphoric,** and thus contaminated

(1) initially that phosphoric contamination made these ores quite useless for steel-making; and

(2) thus Germany was forced to import not only haematite iron ores

(3) but also foreign pig iron for steelmaking.

iii) **The 1878 Gilchrist-Thomas Basic process of steel making,**

(1) thus provided Germany with the necessary means, in a crucial turning point, to utilize profitably the vast deposits of minette or phosphoric iron ore

(2) and especially those deposits in recently acquired Lorraine, from Prussia's 1871 victory over France (Franco-Prussian war: 1870-71).

c) **Protective Tariffs, Cartels, and Growth of the German Steel Industry**:

i) **Tariffs:**

(1) the early years of the German steel era had been marked by Free Trade, with negligible tariffs on iron and steel – because Prussia was still essentially agrarian and pro- Free Trade;

(2) indeed tariffs were virtually eliminated in 1877.

ii) **Depression in the 1870s:**

(1) But the aftermath of the 1873 financial crisis and the ensuing trade depression of the later 1870s ended that Free Trade era, just two years later, in 1879

(2) when both agricultural and industrial interests combined to demand protection: what is called the 'Union of Pork and Iron'.

iii) **Protective Tariffs of 1879 was the response**:

(1) tariffs ranging from 15% to 25% ad valorem on iron and steel products,

(2) and these remained basically unchanged until World War I.

iv) **How important were such tariffs,** since historians agree that the major growth of the German steel industry came only from the 1880s?

v) **German tariffs, Cartels (Kartells) and Cartelisation:**

(1) Perhaps the most important consequence of these tariffs was to promote the development of cartels: monopolistic syndicates or combines:

(2) i.e., by excluding foreign competitive products that could undersell the cartel or disrupt their market sharing schemes.

vi) **Investment Banks, the State and Cartels:** at the same time, however, we mus not neglect the role of two other institutions and factors: in promoting cartelisation

(1) the great German Investment Banks, or Universal Banks: for all the reasons discussed in the previous lecture

(2) The dual role of the state: the government of the German Reich or Empire: in Berlin

- in the first place, of course, tariffs were imposed by the state, as part of government overall economic policy
- but as well the government upheld the legitimacy of cartel organization and cartel structures
- and so did the Supreme Court of Germany, as an arm of the state

vii) **On growth of cartels in iron and steel, read Clive Trebilcock**: [2]

(1) First significant cartel was the German Rail Federation of 1876,

(2) followed by the first of the Pig Iron Syndicates in 1879.

(3) These began as regional or state cartels and became fully national cartels in late 1880s and 1890s, culminating in German Pig Iron Syndicate in 1896;

(4) in 1904, the Stahlwerksverband (national syndicate of all heavy steel producers).

(5) The only major holdout was the Phoenix steelworks;

(6) but the investment banks, allied with other leaders in the German steel industry, used their 15 financial power, via the shares it held in this company, to force the Phoenix company to join the cartel.

(7) And these contractual agreements for cartelisation were subsequently upheld by the German courts.

viii) **The Cartels's selling policies:**

(1) An important method of maintaining their market control was in offering purchasers 5% discounts if they made all their purchases exclusively from the cartel.

(2) Outsiders were either:

- too small to undercut the cartel or

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[2] Clive Trebilcock, *The Industrialization of the Continental Powers, 1780 - 1914* (London and New York: Longman, 1981). A recommended textbook for this course.

- too fearful of retaliation to do so (i.e., fearing oligopolistic price-cutting to drive them out).

ix) **By 1900,** the cartels were responsible for over 80% of Germany's pig iron and steel output.

e) **Economic Significance of German Steel Cartels**:

i) **Negative or Positive?** cartels and other business combines are usually seen to be negative in their consequences,

(1) particularly in misallocating resources and

(2) in charging consumers higher, monopolistic prices.

ii) **For alternative view, we shall consider the classic article of Steven Webb (1980)**.[3]

iii) **His key point is that cartels encouraged, indeed forced vertical integration upon the German steel industry**:

(1) vertical integration in the sense that the major steel firms owned their own coal and iron mines, blast furnaces for pig irone, Bessemer Converters, Open Hearths, rolling mills for finished steel, etc.

(2) but vertical integration also led to horizontal integrations – amalgamations

iv) **Cartels made German steel manufacturers integrate downward in order to avoid paying cartel prices for their inputs**: such as coal and pig iron.

(1) Thus a vertically integrated steel firm paid only the cost price for the required pig iron and coal, while a firm not so integrated would pay about 33% more for the same pig iron.

(2) By 1900, about 76% of total German pig iron was produced by such vertically integrated steelworks.

iii) **Economic Advantages of Vertical Integration**:

(1) **Technological: Significant fuel economies by producing steel in 'one heat'**: i.e.,

- in using the pig iron directly before it cooled down, without having to reheat the cold pig iron (bought from another firm);
- and similarly in rolling and cutting steel to finished sizes while the metal was still hot, and thus easier to work.

(2) **Significant savings on transportation, transaction and administrative costs**: centralized production, with one centralized administration, instead of half dozen or so administrative setups.

(3) **Vertical integration naturally encouraged much larger units of production with much more extensive mechanization**: thus increased economies of scale from vertical integration.

f) **The Landes-McCloskey Debate**:

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[3] Steven Webb, 'Tariffs, Cartels, Technology, and Growth in the German Steel Industry, 1879 to 1914', *Journal of Economic History*, 40 (June 1980), 309-30. Regrettably, he seems to have dropped out of the profession.

i) **Long before Webb, in 1969, David Landes had alluded to many of these same arguments in his book *The Unbound Prometheus***:[4]

(1) in discussing cartelisation, amalgamation, and the growth of very large scale units in the German steel industry, Landes pointedly observed that German steelmakers **'put big and big together, while the British kept small and small apart':**

(2) i.e., the British, with free trade and a legal system insisting much more strongly on competitive markets, had a steel industry with much smaller, competing units, and no really effective cartels.

ii) **He made the following points in his comparisons**: and in fact all of these points were reiterated by Steven Webb:

(1) that German steel plants were about four times the size of the British;

(2) that the larger scale German firms were far more extensively mechanized throughout: from handling iron ores, coal, and pig iron to the finished steel products;

(3) that, in particular, the German were far more efficient in use of fuels.

ii) **In 1971, however, Professor Donald [now Deirdre] McCloskey indirectly challenged Landes**: in a now famous paper.[5] Indeed McCloskey has been carrying on a crusade to rescue the reputation of British industry in the late Victorian era.

Here are his comparative data for Germany, the U.K, and the U.S. for 1906-13

International Comparisons in Steel Production, 1906-1913
Price and Costs of Steel Production in Germany, U.S., and Great Britain

A. McCloskey on British-American Productivity Differences				
Steel Product (1907-09)		**British Advantage**		**American Advantage**
Heavy Plates		1.57%		
Rails				8.13%

[4] David Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (London and Toronto: Cambridge University Press, 1969; 2nd edition, 2003), pp. 249-69.

[5] Donald McCloskey, 'International Differences in Productivity? Coal and Steel in America and Britain Before World War I', in D.N. McCloskey, ed., *Essays on a Mature Economy: Britain After 1840* (Princeton, 1971), pp. 215-34..

A. McCloskey on British-American Productivity Differences				
Steel Product (1907-09)		**British Advantage**		**American Advantage**
Bars, Rods				7.22%
Structural Steel				5.94%
Blank Plates, Sheets		1.85%		
B. German & American Production Costs as percent of British production costs in 1913				
Input		**German (1906-13)**		**American (1910-13)**
Iron Ore		69.0%		97.0%
Fuel		88.0%		65.0%
Scrap Metal		95.0%		99.0%
Labour		72.0%		170.0%
Average Unit Costs		**72.0%**		**90.0%**
Total Factor Productivity (gains		**115.0%**		**115.0%**

A. McCloskey on British-American Productivity Differences				
Steel Product (1907-09)		**British Advantage**		**American Advantage**
C. Steel Prices, in Shillings Sterling per Metric Ton: mean of 1906-13 = 100				
Steel Product	**German Domestic**	**German Export**	**American Domestic**	**British Domestic**
Steel Rails	n.a.	110	115	121
Steel Bars	106	106	127	139
Heavy Plates	124	119	132	139
Stuctural Steel	114	107	133	130
D. German & American Steel Prices as percentages of British Prices				
Steel Product	**German Domestic**	**German Export**	**American Domestic**	
Steel Rails	n.a.	90.9%	95.0%	
Steel Bars	76.3%	76.3%	91.4%	
Heavy Plates	89.2%	85.6%	95.0%	
Structural Steel	87.7%	82.3%	102.3%	

(1) In essence, McCloskey contended that the American and British steel industries were about on a par in terms of productivity.

- But his own statistics show that the American steel industry was evidently more efficient than the

British in making steel rails, bars and rods and structural steels,

- while the British steel industry had only a slight advantage in heavy plates, blank plates, and sheets.

(2) McCloskey further contended that his figures contained some biases, which, if eliminated, would reduce the American advantage in the above categories to about 2% - 3%.

(3) McCloskey was not comparing Britain with Germany, please note, but with the U.S. -- on the grounds that everybody considered the U.S. steel industry to be the world's most efficient around 1900.

(4) But other figures suggest that, while the American industry was indeed more efficient than the British, it was still less efficient than Germany's, ca. 1910.

iii) **Subsequently, McCloskey's statistics and methodology were seriously challenged,** not only by Steven Webb (in the 1980 article cited above), but also, a year earlier, by Robert Allen, in an equally important journal article.[6]

(1) Both Webb and Allen attack McCloskey's statistics: their data indeed do support the traditional view that the German steel industry had become markedly more efficient than the British by the 1890s.

(2) Allen states that both the American and German steel industries were about 15% more productive than the British by 1905.

(3) Webb is somewhat more conservative, giving the German industry only a 10% lead by that date.

(4) Allen's cost figures can be seen in the table on the screen (section C):

- for Germany, he contends that by the 1880s, the major factors for the German steel industry were a sharp drop in the costs of raw material (use of minette or phosphoric ores) and coal fuels;
- for the U.S., the advantage lay chiefly in fuel economies.

(5) As for labour costs, Allen and Webb disagree.

- Allen believes that German labour costs were lower, only 72% of the British: with higher efficiency and lower wages;
- but Webb believes that there was little difference: contending that British labour efficiency was higher, but was offset by lower German wages.

(6) For Webb, as already noted, the key German advantages lay in much larger scale with vertical integration and extensive mechanization: along with cheaper raw materials and fuels.

(7) As for comparative steel prices, note from Allen's table on the screen (sections A and B) how much cheaper German steel was than the British, for the categories listed, on the export markets:

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[6] Robert Allen, 'International Competition in Iron and Steel, 1850-1913', *Journal of Economic History*, 39 (Dec. 1979), pp. 911-38.

- from 10% cheaper in steel rails to almost 25% cheaper in steel bars.
- In the domestic market, cartels certainly raised the price over the export market;
- but even so, domestic German prices were still markedly cheaper than domestic steel prices in Britain (or the U.S.).

g) **The German Steel Industry in 1900**:

i) **by the 1890s, Germany had overtaken Britain in aggregate steel production;**

(1) and by 1913, was producing more than twice as much steel as Britain: 16.2 million tonnes vs. 6.9 million tonnes in Britain.

(2) Indeed, on eve of WWI, Germany was producing more steel than her three opponents combined: Britain, France, and Russia -- but only half as much as U.S.

World steel production, 1865 - 1910

in Thousands of Metric Tons (2,204.6 lb.)

Year	**Britain**	**Germany**	**U.S.**	**WORLD**
1865	225		100	
1870	286	169	68	703
1880	1,320	660	1,267	4,273
1890	3,637	2,161	4,346	12,096
1900	5,130	6,645	10,382	28,727
1910	6,374	13,698	26,512	58,656

ii) **By the early 20th century, the German steel industry had became the world's leading exporter:** with the U.S. close behind, though producing most its output for the far larger domestic market.

iii) **Indeed, 70% of Germany's of rolled steel went to British markets:**

(1) with free trade, and the gold standard (i.e., to prevent currency depreciation as a protective measure) Britain provided no barriers to the entry of such German steel products,

(2) much cheaper steels were now underselling British steels.

j) **The British Steel Industry in the face of German and U.S. competition**:

i) **Not surprisingly, Britain's share of world steel markets shrank drastically**: in the face of this German and American competition.

ii) **But the British steel industry did not disappear**: how did it survive?

(1) It survived by obeying the Law of Comparative Advantage.

(2) Thus, German superiority was based on very large scale production,

- which thus also meant concentrating production chiefly on a few lines of cheaper bulk steels,
- chiefly using the Bessemer converter (Basic process).

iii) **The British industry responded to the German advantages by seeking its own relative or comparative advantages**:

(1) by switching more and more to the production of high quality steels using the Siemens-Martin Open Hearth process,

(2) in which the British certainly had a comparative if not absolute advantage.

(3) Consider these figures:

Percentage of Total Steel Production by Siemens-Martin Process

	Great Britain	**Germany**
1890	44%	17%
1913	79%	40%
1930	94%	52%

iv) **But as suggested before,** this shift to Siemens-Martin also reflected the much more highly industrialized and developed nature of the British domestic economy (and the relatively greater supply of scrap metal).

v) **Note that as the German economy became more developed,** its steel industry similarly also shifted more towards Siemens-Martin Open Hearth.

4. <u>**German Mastery in the New Chemicals Industry**</u>

a) **The traditional chemicals industry was heavily based on soda chemicals for soaps and bleaching**: especially for textile production

i) **in this industrial field, as late as 1860,** the German industry had been well behind France, Britain, and Belgium.

ii) **But subsequently, from the 1880s,** the German industry surged rapidly forward to gain not just European but world supremacy in the production and marketing of chemicals.

b) **Germany's key advantages**:

i) **Advantages in raw materials**:

(1) immense deposits of potash (potassium salts) at Stassfurt,

- the world's largest,

- so very valuable for chemical fertilizers.

(2) large sulphur deposits.

(3) most important of all, large coal deposits: for coal provided the true foundations for the modern chemicals industry (followed by petroleum and wood cellulose).

(4) But, since Britain had larger coal deposits than Germany, then clearly natural resource endowment had to be only secondary, to some other factor, to which we now turn:

ii) **The advantage of being a late starter**:

(1) meant that Germany did not have to overcome the problem of large sunk costs;

(2) It was not encumbered by large prior investments in capital and technology in older forms of chemical production.

(3) Most economists would say that this is an irrational argument: since the best advice to be given to any enterprise faced with change and competition is to ignore sunk costs and to re-invest: ‘Let bygones be bygones’ is the almost universal adage and advice.

(4) But we will see that in fact businessmen, rightly or wrongly, do not relish the prospect of ignoring sunk costs, and junking their prior investments.

(5) That error will be noted in the failure of the British chemical industry, which had very large sunk costs.

iii) **German science**: scientific leadership, with very strong links between science, engineering, technical education, and industry, frequently cited as a major advantage, and this topic deserves now our attention and special treatment.

c) **Science and Industry in Germany and Britain: A Contrast?**

i) **The following are the chief features of the now standard view:** about the role of science and education that favour Germany:

(1) Far many more managers and executives in German business corporations had had scientific training, particularly as engineers,

(2) and far many more engineers were employed by German business companies than were to be found in British or French companies.

(3) In German universities and schools, science received far more emphasis than in British or French educational institutions; and 19th century Germany had far many more technical and engineering schools than did other countries.

(4) To quote not just Landes but more recently Alan Milward and S.B.Saul, in their *Development of the Economies of Continental Europe, 1870 - 1914* (1977), p. 35:

> A scientific chemical education was available in many German universities, and cheaply

> available, to the young men of talent, whereas in Britain and France it was expensive, difficult to find, and almost non-existent in the universities. This was one of the latest benefits of the Enlightenment in Germany.[7]

(5) Recall that in this era British university education, which was then primarily took place at Cambridge and Oxford, remained solidly wedded to Greek and Latin classical education, to literature and philosophy.[8]

(6) The newer secondary universities that did emphasize sciences, the so-called 'red-brick' universities (Birmingham, Leeds, etc.), were not really important until after 1900.

(7) Milward and Saul (1977) note that the German chemical industry began by importing foreign knowledge and ended up with a virtual monopoly on chemical knowledge.[9]

(8) Trebilcock (1981) notes that, in the 1870s, the University of Munich had more graduate research chemists than all English universities combined.[10]

ii) **Inevitably such a contrast between Germany and Britain was going to be challenged**:

(1) as it was in an article by two German historians, Hartmut Berghoff and Roland Möller (1994):[11]

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[7] For explanation of the term Elightenment, from the *Britannica Concise Encyclopedia:*
European intellectual movement of the 17th – 18th century, in which ideas concerning God, reason, nature, and man were blended into a worldview that inspired revolutionary developments in art, philosophy, and politics. Central to Enlightenment thought were the use and celebration of reason. For Enlightenment thinkers, received authority, whether in science or religion, was to be subject to the investigation of unfettered minds. In the sciences and mathematics, the logics of induction and deduction made possible the creation of a sweeping new cosmology. The search for a rational religion led to Deism; the more radical products of the application of reason to religion were skepticism, atheism, and materialism. The Enlightenment produced modern secularized theories of psychology and ethics by men such as John Locke and Thomas Hobbes, and it also gave rise to radical political theories. Locke, Jeremy Bentham, J.-J. Rousseau, Montesquieu, Voltaire, and Thomas Jefferson all contributed to an evolving critique of the authoritarian state and to sketching the outline of a higher form of social organization based on natural rights. One of the Enlightenment's enduring legacies is the belief that human history is a record of general progress.

[8] This point was stressed in the first-term lecture topic (no. 3) on Science, Education, and the Dissenters: in comparing traditional Classical-oriented English education with Scottish and Dissenter education in the 18th century, with far greater emphasis on maths and sciences and accounting.

[9] Alan Milward and S.B. Saul, *The Development of the Economies of Continental Europe, 1850 - 1914* (London, Allen and Unwin, 1977).

[10] Clive Trebilcock, *The Industrialization of the Continental Powers, 1780 - 1914* (London and New York: Longman, 1981).

[11] Hartmut Berghoff and Roland Möller, 'Tired Pioneers and Dynamic Newcomers? A Comparative Essay on English and German Entrepreneurial History, 1870 - 1914', *Economic History Review*, 2nd ser.,

(2) Thus they snidely comment that:

> One popular misconception in the debate about British [and German] entrepreneurship is the cliché of the German businessman who had been prepared for the practical requirements of his job in the *Realschule*, with its strong emphasis on science and modern language teaching. His English counterpart is assumed to have attended one of the exclusive public schools, where his business acumen had been extinguished once and for all by excessive classical studies and by initiation into aristocratic lifestyles and snobbery.

(3) They note, however, in their comparative sample of 1324 German and 1328 English businessmen,

- that only 15% of the German businessmen had attended a *Realschule*, while fully 60% had instead attended the more widespread and popular *Gymnasiums*, 'which focussed heavily on classical studies'.
- In England, furthermore, only 18% of businessmen studied had attended one of the exclusive public [i.e., private] schools.

(4) They do not make clear whether they think that English grammar schools and German *Gymnasiums* were on a par;

(5) my impression remains that the German *Gymnasiums* were superior.

iii) **Their comparisons of university education, however, seem to support the standard views outlined above favouring Germany**:

(1) Certainly there is a striking difference in the proportions of businessmen who attended university

- They admit that while only 13% of English businessman had university education -- almost entirely at classically-oriented Cambridge and Oxford
- but fully 24% of German businessmen (almost double) had such university education, and a more scientifically oriented one.
- In 1913, as they note, 60,000 students were enrolled full time at German universities (in a population of 65 million: 0.09232%)
- but only 9,000 in British universities (in a population of 41 million, i.e., 63% the size of Germany: 0.02195%):
- in relative terms, the university participation rate in Britain was only 23.78% as much as the German participation rate.

(2) Proportionally more German businessmen went to universities: the question is thus why?

- because the German state governments had long promoted university education, at various levels, and
- especially polytechnical education to train their officials and civil servants, drawn from the same social pool as businessmen.

47:2 (May 1994), 262-87.

(3) Most German states had established polytechnical universities from the 1820s (with 7,489 students collectively, in 1914).

(4) They also note that in 1900 German state funding for science and technology was 12.3 million marks, while the corresponding amount in Britain was under 1/6th (16.26%) that, about 2.0 million marks.

(5) Thus, as they concede, 61% of academically trained German businessmen had studied scientific or technological subjects (and only 20% had studied law.)

(6) Furthermore, in their sample, most businessmen and executives in the new chemical industries held university science degrees.

(7) They also admit that many English businessmen 'cultivated strong anti-academic prejudices, which survived well into the twentieth century'.

(8) For example, they note that the establishment of the Faculty of Commerce at Birmingham in 1902 attracted disappointingly very few British students, and proportionately far more from the Far East.

(9) They comment that: 'Although local [British] businessmen had made an enormous effort towards the faculty's establishment, they did not consider it a proper place for the education of their own sons'.

(10) The role of managerial businessmen in Germany is another striking contrast found: i.e., so many German businesses run by hired or salaried managed, in contrast to the still overwhelming predominance of owner-operated businesses in Britain, which also reflects scale differences in industry.

(11) In Germany, a high proportion of salaried managers had university degrees

- 65% vs. only 27% for industrial owners
- and they had also travelled widely.
- They note that: 'Very often they had gathered professional experience with a multitude of firms all over Germany and Europe before they were appointed to directorships'.

(12) Thus 72% of German businessmen had lived and worked outside their own country, compared to only 22% in Britain.

(13) Also worth noting: the question of business and politics:

- Germany's less well developed and certainly much less democratic political structures had far less appeal in drawing members from the same socio-economic pool into politics than in Britain;
- in Britain, in contrast, a political career was highly desirable, indeed attracting many businessmen.
- Thus proportionally more of the brightest in Germany went into and stayed in business.
- In Britain, 36% of all peerages created from 1880 to 1919 went to businessmen;
- but in Germany only 11% of noble titles went to businessmen in the same period.
- Implication and question to be asked: to what extent are fully democratic political structures really

necessary for economic growth, since Germany was clearly less ‘democratic’ than was Great Britain (or France, for that matter)

iv) **From statements, notes, etc. in their article,** I have constructed this table, which summarizes most of the comparative evidence:

Comparison of Businessmen in Germany and Great Britain 1890 - 1910:

in terms of Science and Education

Characteristics of Businessmen	Germany	Great Britain
Attending Schools: Gymnasium/Grammar	59%	30%
Businessmen Attending University	24%	13%
University Students enrolled	60,000	9,000
Populations 1910	65 million	41 million
State Funding of Science and Technology	12.3 million marks	2.0 million marks
Businessmen who studied science & technology	61%	(very small)?
Business Managers with university degrees	65%	n.a.?
Salaried managers	28%	7%
Businessmen who had lived and worked outside country	72%	22%
Peerages granted to Businessmen	11%	36%

Characteristics of Businessmen	Germany	Great Britain
Businessmen with political affiliations	4%	46%

Source: Hartmut Berghoff and Roland Möller, 'Tired Pioneers and Dynamic Newcomers? A Comparative Essay on English and German Entrepreneurial History, 1870 - 1914', *Economic History Review*, 2nd ser., 47:2 (May 1994), 262-87.

v) **Let us now turn to the first of these chemicals industries:** as based on advanced science and technology.

d) **The Development of Organic or Aniline Dyes from Coal Tars**:

i) **dyestuffs had obviously always been a very vital part of all traditional textile industries from ancient to modern times.**

(1) Indeed, in the medieval and early modern textile industries, the greatest profits were made in dyeing and finishing cloths;

(2) and uncoloured clothing would be as unthinkable as a colourless world.

ii) **The basic problem that dyeing posed for the modern textile industries was their often costly and inelastic supply**:

(1) for dyestuffs were all extracted from various plants and even insects (in case of scarlet dyes),

(2) many of which were imported from Asia or Latin America, often at high cost, because of the vast distances and shipping risks involved.

iii) **With the great expansion in textile production of all kinds in Europe and Americas from the mid-19th century, dyestuffs provided a production bottleneck**:

(1) the supply of dyestuffs simply could not keep pace with that industrial expansion in textiles.

(2) Hence the need for some cheaper synthetic dyestuffs in far more elastic supply.

iv) **These synthetic or artificial dyes were organic compounds extracted from coal tars:**

(1) in a form known technically as aniline dyes.

(2) The first such extraction (a mauve or purple colour) occurred not in Germany

- but in England: in 1856,
- by a scientist named William Perkin (1838-1907): and at the remarkable age of 18
- He had attended (from age 15) the Royal College of Chemistry, in London
- but his chief mentor was a German chemist, and head of the college: August Wilhelm Hofmann

v) **Nevertheless, despite Britain's abundance of coal and coal tars,**

(1) an organic aniline dyestuffs industry failed to develop in Great Britain, on any major scale .

(2) even though William Perkin did, virtually by himself (and later with his son), establish the aniline dye industry in Great Britain.

vi) **Germany instead took up Perkin's discovery to develop an aniline dyestuffs industry;** and by the 1870s, Germany was accounting for half of the world's production of all kinds of dyestuffs; by the 1890s, for 90%.

vii) **By this time, aniline dyes had completely displaced all natural dyestuffs:**

(1) they were not only vastly cheaper, but much 'faster' (i.e., in holding to the textile fibres without fading or discolouring, with water and sun),

(2) and more variable in their shades.

viii) **The largest German firm producing such dyestuffs was BASF:**

(1) Badische Anilin und Soda Fabrik, a name signifying the two key branches of the new chemicals industry

(2) in the German city of Baden Baden, in the Black Forest area of the state of Baden-Württemberg.

d) **The Solvay Process**:

i) **to make alkalis for soaps, bleaching powders, glass, explosives, etc:** and its historic significance must be understood in the light of the earlier processes that it displaced.

ii) **The LeBlanc Process:** had been developed in 18^{th}-century France.

(1) was the name given to the traditional process for producing alkalis.

(2) It was a very costly and rather filthy process using sulphur, hydrochloric acid, calcium, and raw coal (thus polluting the countryside).

iii) **Ernest Solvay was a Belgian scientist who discovered the much superior method,** bearing his name, in 1863 (Brussels);

iv) **but again it was the Germans,** rather than the French or British, who took up this process and developed it into a great industry that achieved world mastery.

v) **The Solvay Process**: combined ammonia – a Nitrogen-Hydrogen compound extracted from coal tars – with salt, water, and carbon dioxide to produce both ammonium chloride and sodium bicarbonate very cheaply: according to this formula

$$NH_3 + NaCl + H_20 + CO_2 \Rightarrow NH_4Cl + NaHCO_3.$$

vi) **the Solvay process, despite a hefty royalty,** decisively undersold the LeBlanc process, by some 20%.

vii) **The Belgians, the French, and of course the Germans:** all quickly switched to the new Solvay process -- with the German production becoming by far the largest by 1900.

viii) **Only the British, with a very heavy investment in the LeBlanc process, refused to switch**.

(1) As Landes has shown, the British industry survived a generation of competition with frantic cost-cutting; but eventually it succumbed -- by 1920, indeed, it was extinct.[12]

(2) Here economic history provides the best example of why a rational industry or firm should ignore sunk costs and instead invest in the future.

e) **Other Coal-based chemicals produced by Germany**:

i) **a very wide range of pharmaceuticals,** including aspirin (Bayer), laxatives, saccharin, disinfectants,

ii) **and also:** perfumes, photographic chemicals, high explosives; various ammonia compounds, etc.

f) **Chemical Fertilizers**: as noted before based on potassium (potash) and nitrogen (coal) compounds; and byproducts of German steel industries.

g) **The German chemicals industry by 1914**:

i) **collectively it accounted for 25% of the world's total production of chemicals of all varieties,** including 90% of dyestuffs, as noted.

iii) **The United States (Dupont) was the chief competitor,** with Great Britain far behind, though later advancing after World War I with Imperial Chemicals Industries:

iii)**The largest German chemicals firm also came to be the world's largest (after WWI, in 1925):**

(1) I.G. Farbenindustrie: founded in December 1925.

- in a mammoth conglomeration, a world-dominating cartel
- composed of the former German chemical giants: as a merger of the following six companies: BASF (27.4 percent of equity capital), Bayer (27.4 percent), Hoechst including Cassella and Chemische Fabrik Kalle (27.4 percent), Agfa (9.0 percent), Chemische Fabrik Griesheim-Elektron (6.9 percent) and Chemische Fabrik vorm. Weiler Ter Meer (1.9 percent).
- note that *farben* is the German verb for dyeing

(2) and, with no bad pun intended, I.G. Farbenindustrie became notorious under the Nazi regime for producing Zyklon-B gas in the Holocaust: i.e., the mass murder of millions of Jews, Roma [‘gypsies’] and Slavs, and others, during World War II

(3) Seized by the victorious allies, after the end of the Nazi regime, in 1945, it was liquidated in 1952: in effect broken up into most of its former units – but still a legal entity today[13].

(4) Today Agfa, BASF, and Bayer remain, Hoechst having in 1999 demerged its industrial chemical

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[12] Landes, *The Unbound Prometheus: Technological Change and Industrial Development*, pp. 269-73.

[13] See Appendix I on IG Farbenindustrie

operations to Celanese AG and merged its life-sciences businesses with Rhône-Poulenc's to form Aventis.

iv) **To quote David Landes, from his *Unbound Prometheus*, p. 276:**

'In technical virtuosity and aggressive enterprise, th[is] leap to hegemony, almost monopoly, has no parallel. It was Imperial Germany's greatest achievement'.

v) **By 1913:** the chemicals industry had created 290,000 jobs, the fourth ranking source of industrial employment after textiles, coal mining, and metallurgy:

Industrial Employment in Germany, 1913

Chemicals	290,000
Metallurgy	443,000
Coal Mining	728,000
Textiles	1,100,000

v) **Certainly the German chemicals industry was one of Germany's most rapidly growing industries after 1870,** but only the second most rapid, after the electrical industry, to which we now turn.

5. <u>German Mastery in the Electrical Industry</u>

a) **The new electrical industry**: was the other major industry in which Germany gained world leadership in late 19th century, when it was also Germany's most rapidly growing industry.

b) **German advantages are again based on**:

i) **scientific leadership:** and close links between science and industry.

ii) **resource endowment:**

(1) very abundant coal supplies.

(2) Why coal again? Because electrical power generation was then almost entirely coal-based on coal-fired steam turbines to operate the generators (dynamos).

iii) **Investment Banks, this time, provide a third reason (virtually absent from the chemicals industry):** in supplying massive amounts of capital financing, obviously necessary for electrical power generation and distribution; and in supplying support for scientific research.

c) **For the origins and develop of electrical power generation and application, read Landes**:[14]

i) **beginning in 1831:**

(1) with Michael Faraday (1791 - 1867): English chemist and physicist, chiefly famed for his discovery of electromagnetic induction,

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[14] Landes, *The Unbound Prometheus: Technological Change and Industrial Development*, pp. 281-90.

(2) and the invention of first electric dynamo.[15]

(3) Published the three volume study *Experimental Researches in Electricity* (1839, 1844, 1855);

ii) **The first practical application of that was the electric telegraph,** first in Britain in 1837, followed by the U.S. in the next year (1838).

d) **The German Electrical Industry**:

i) **the veritable founder and father was Werner Siemens (whose brother was William Siemens, of open hearth fame)**: Siemens' father had founded an electric telegraph company in Berlin.

ii) **In 1866-67,** Werner Siemens perfected (with others) an electric dynamo to produce much cheaper electric power, first for the telegraph.

iii) **In 1878, he invented an electric furnace generating extremely high temperatures,** for making special steel alloys.

iv) **In 1879, Siemens produced perhaps his greatest invention:**

(1) electric traction for powering trams and trains for urban and inter-urban transport;

(2) and that invention for mass transport was the one that aroused the interests of the German investment banks.

e) **Other Important Electrical Inventions of this era**:

i) **1870:** Gramme's ring dynamo for producing direct current.

ii) **1876:** Alexander Graham Bell's telephone [16]

iii) **1879:** Thomas Edison's incandescent lamp for electric lighting.

iv) **1880:** Nikola Tesla's D.C. induction motors

(1) though d.c. and a.c. induction motors for electrical machinery were not, in fact, perfected until the 1890s).

(2) The first electrically powered factory was an American cotton mill in 1894.

v) **1884: Charles Parsons' steam turbine:** steam-turbine powered dynamos that permitted mass generation of electric power at very low marginal cost, as crucial factor in mass consumption of electric power.

vi) **1886:** The Hall-Héroult method of making aluminum.

vii) **1895:** Marconi's invention of the wireless radio.

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[15] Faraday built the first dynamo, a copper disk that rotated between the poles of a permanent magnet and produced an electromotive force (something that moves electricity). His work in electromagnetic induction led to the development of modern dynamos and generators. Faraday also discovered the compound benzene. From: Answers.com

[16] See the Appendix on Bell and the telephone. Born in Scotland in 1847, he and his family lived briefly in Branford, ON, but then moved to the US, to Boston, where he invented the telephone in 1876. He later moved back to Canada, dying in Nova Scotia in 1922 (at age 75).

f) **The importance of industrial urbanization**: in making the modern electrical industry economically feasible:

i) **mass urban transportation:** electrically powered trams and streetcars.

ii) **electric lighting:** of streets, homes, and factories.

iii) **mass communications,** with the telephone.

g) **The German electrical industry began its rapid growth in the 1880s**: in form of very large scale technically complex units, of which two giant cartels came to dominate the entire German electrical industry.

(i) **The German Edison Company, formed in 1883,**

(1) which later combined with other firms to form the giant cartelised firm A.E.G. (Allgemeine Elektricitäts Gesellschaft)

(2) founded by Emil Rathenau [father of the German diplomat of the 1920s, who was assassinated in the 1930s].

(ii) **the equally famous Siemens-Schükert:** was the other rival, giant cartelised firm (employing 57,000 by 1913).

h) **German Supremacy in the Electrical Industry**: by the 1890s, Germany was well ahead of Britain and all other European countries in applying electric power to transportation, lighting, and industry, especially industry:

(i) **first industrial application were in electric metallurgy:**

(1) Siemen's electric steelmaking furnace;

(2) and also electric chemistry: for producing chlorine, sodium, sodium cyanide, caustic sodas, aluminum.

(ii) **From the 1890s,** the application of electric d.c. and a.c. induction motors for powering industrial machinery and hand tools.

(iii) **By 1913,** about half of Berlin's engineering industries had switched from steam engines to electrical engines, while such a switch had only barely begun in Britain (and would not really begin until the late 1920s).

(iv) **By 1914, the German electrical industry was exporting a very wide range of electrical goods:** from electric dynamos, electric trains, etc. to machines, tools, household appliances and consumer goods.

(v) **German exports were 2.5 times those of the U.S. or Britain,** indeed accounting for about 50% of world trade in electrical goods.

(vi) **To quote Sir John Clapham,** *Economic Development of France and Germany* (1921), p. 308:

(1) ‘Beyond question, the creation of this [electrical] industry was the greatest single achievement of modern Germany.’

(2) Compare this with Landes's comment on the German chemical industry, quoted earlier.

6. **Industrial Cartels in Germany**

a) **Industrial cartels, combines, or other monopoly arrangements**: are certainly a most striking feature of the German industrial economy during the later 19th and early 20th centuries (from 1880s to 1914):

i) **cartels came in various forms**: industry-wide agreements on a regional or national basis to fix prices, or to divide up the market, or to set sales quotas.

ii) **organizations also varied**:

(1) agreements to fix prices or share the markets;

(2) centrally supervised syndicates of independent firms;

(3) outright mergers or amalgamations.

iii) **cartels are by no means a unique German phenomenon**: they can be found almost everywhere in late 19th century.

(1) But nowhere were cartels so widespread, so socially acceptable, or indeed so government protected and judicially enforced as in Germany.

(2) In Britain and the U.S., it must be stressed, such cartel arrangements were officially illegal.

(3) In the U.S.: the Sherman anti-Trust Act (1890) provided strong federal legislation against cartels.

b) **Factors in the Development of German Cartels**: summary

i) **long historic tradition of government sanctioned guilds**: and government sanctioned cartel-arrangements in many German states.

ii) **The combined Financial-Commercial crises and trade depressions of the 1870s and 1880s**:

(1) especially for metallurgy and other heavy industries.

(2) Cartels were formed to prevent industrial collapse: to shore up prices and divide up depressed markets.

iii) **The Return to Protectionism, with the 1879 Tariffs**:

(1) as a result of depression of the 1870s.

(2) As I stressed before, in discussing the steel industry, tariffs were absolutely necessary, in keeping out foreign competitors, to maintain cartels.

iv) **The role of the German Investment Banks, as noted previously**:

(1) especially in the iron, coal, steel, and electrical industries (though not so much in the chemicals industry).

(2) The steel industry: investment banks, even if at the urging of other steel firms, used their large block of

voting shares to force the Phoenix Ironworks to join the Stahlwerksverband in 1904.[17]

v) **The Role of the Government via the Courts**: the German government actively promoted and sanctioned cartels:

(1) with the support of the German Supreme Court: in 1897, the Supreme Court ruled that cartel agreements were legally binding contracts under German law (as noted earlier, with the steel industry).

(2) In 1903, a government commission did criticize some cartel activities but recommended only reforms, not abolition of cartels.

(3) 1904: government supported formation of the Stahlwerksverband (steelmakers cartel).

c) **oligopoly**: **Industrial structures promoting cartels**:

i) **Not all industries readily lent themselves to cartel structures:**

(1) not those engaged in genuine monopolistic competition with highly differentiated products.

(2) Such product differentiation made cartel regulation almost impossible to enforce (since products kept changing).

ii) **Thus the industrial structure that was best subjected to cartelisation was oligopolistic competition**: i.e., production of certain commodities by a few large sellers

iii) **that was particularly true in those industries, as noted before, with two chief characteristics:**

(1) production of relatively homogenous products by a few firms.

- Thus a steel firm, for example, might manufacture several grades of steel;
- but each grade of steel would be undifferentiated from that produced by the few rival firms.

(2) industrial production with high barriers to entry: involving large scale, complicated technology, high initial capital investment costs.

iv) **Examples are coal, pig-iron, steel, potash, chemicals, etc.**

(1) So important is the homogeneity condition (undifferentiated products) that we find separate cartels for various kinds of coal, iron, steel, and chemicals.

(2) As chart on the screen shows, 62 cartels in iron and steel, 19 in coal, 46 in chemicals.

(3) Consequently we also find that any given industrial firm might belong to a half dozen or more cartels, one

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[17] This is certainly the traditional view, but one contested by Jeremy Edwards and Sheilagh Ogilvie, ‘Universal Banks and German Industrialization: A Re-Appraisal’, *The Economic History Review*, 2nd ser., 49:3 (August 1996), 429: they contend that not the investment banks but other German steel firms, led by Thyssen, forced Phoenix to join the cartel. Their critical viewpoint received an endorsement in the most recent contribution to the debate (which nevertheless seems to be moot): Caroline Fohlin, ‘Universal Banking in Pre-World War I Germany: Model or Myth?’, *Explorations in Economic History*, 36:4 (October 1999), 305-43.

for each of the products that it manufactured.

v) **Oligopolistic competition of this type, with undifferentiated products,** was, as noted before:

(1) inherently unstable, often producing cutthroat competition with price slashing designed to eliminate weaker rivals.

(2) see the appended graph on oligopolistic pricing policies, via game theory.

(3) Investment banks promoted cartels to prevent industrial wars (especially in depressed times) that threatened their investments.

(4) But the 1901 financial-industrial crisis could not be prevented by cartels.

vi) **Cartels also required high barriers to entry**:

(1) so that new competitors would not be attracted into the industry by the growth of any economic rents or monopoly profits that were produced by cartels.

(2) While new entrants might be forced to join the cartel, their entry made cartels less manageable and threatened the profit positions of current members.

(3) Oligopolistic competition of this type generally and necessarily meant restricted entry, by the technological and capital-cost structure of the industry.

(4) But entry and competition were also controlled by protective tariffs, by court-sanctioned cartel contracts, and by the investment banks.

d) **In Germany by the early 20th century, some 385 cartels were officially in operation**:

i) **Such cartels accounted for 90% of the market in paper products,** 85% in iron and steel, 74% in mining, 48% in cement; and full 100% in potash.

ii) **Some of the leading cartels were**:

(1) the Rhine-Westphalian Coal Syndicate of 1893;

(2) the Pig-Iron Syndicate of 1896;

(3) the Potash Syndicate of 1888, enlarged in 1910 by government edict;

(4) the Stahlwerksverband (German Steelworks Association) of 1904 (encompassing 27 previous cartels).

iii) **Some cartels resulted in complete industrial mergers**: such as:

(1) A.E.G. and Siemens-Schükert in electrical;

(2) I.G. Farbenindustrie in chemicals (from 1925);

(3) and Krupp in iron and steel.

iv) **Other cartels are listed on the screen (table in the Appendix):**

v) **on this subject,** read Clive Trebilcock, *Industrialization of the Continental Powers, 1780 - 1914* (London, 1981), pp. 65-73, 97-100, 269-70.

e) **Were Cartels Good or Bad for the German Economy?**

i) **As noted before, in discussing the steel industry, traditional economic theory states that cartels or other such monopoly arrangements are economically harmful and wasteful**:

(1) that they lead to inefficiency and resource misallocation and thus to higher prices: higher prices providing economic rents or monopoly profits for the producers (even if the cartel has to set a price where MC = MR).

(2) That they permit price discrimination:

- i.e., charging a higher price domestically than in foreign markets,
- thus robbing the domestic consumer of the so-called consumer surplus.
- For the German steel industry, statistics certainly do indicate that such price discrimination was pursued.
- but they also show that the higher German domestic steel prices were generally lower than comparable steel prices in Great Britain, France, and other European countries.

ii) **But cartels did offer some compensating advantages**:

(1) they provided greater industrial and thus employment stability during the trade crises of the later 19th century:

- the 1870s and 1880s especially, smoothing out some price fluctuations and avoiding industrial collapses and wider spread unemployment,
- even if, however, they did not prevent the 1901 industrial crisis.

(2) Cartels may have been preferable to unstable oligopolistic competition, as suggested earlier.

(3) Joseph Schumpeter's theory of technological advancements: that cartels provided firms with both the necessary industrial stability and the profits to invest in industrial research, as key to innovation.

(4) Indeed, consider the opposite: perfect competition, ‘ price-taking’, with so many small sellers that none could influence the market price.

- That would also likely mean that no firm was big enough and profitable enough to invest in research.
- Even a large firm will not invest heavily in the uncertainties of research if it is worried about its profits, cash flows, and market shares.

(5) Certainly the recent evidence strongly suggests that in the past century, the bulk of technological innovation in industry has come from large-scale cartelised firms (electricity, electronics, chemicals).[18]

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[18] It is certainly true that some major and very important innovative modern firms, such as Microsoft, began very small (virtually in a garage workshop), with crucial and market-determining innovations. At the same time, however, Microsoft’s initial success was soon to be based on alliance with the giant and long-established corporation IBM (International Business Machines). And then Microsoft grew rapidly and grew so large that it no longer needed IBM. Achieving market dominance (though not a cartel), and achieving enormous scale, with equally enormous capital resources, it surely fits the paradigm of the such large-scale,

iii) **Cartels and Industrial Innovations?**

(1) An obvious question to be asked is the following: if cartels acted as monopolistic structures to suppress competition, to fix market prices, and market shares, and thus to extract (extort) monopoly ‘rents’ from the economy, why would cartels invest in, let alone be interested in industrial innovation?

(2) The most obvious reason, to answer that question, lies in the following division of markets

- the domestic market: the only one in which cartels could achieve those objectives – and only so long as they were supported by the state: with protective tariffs and judicial protection of cartel agreement
- in the international markets, however, German industrial cartels had to face strenuous competition from foreign rivals: the British, French, and especially American

(3) The other incentive for investing in and achieving industrial product innovations lay in the rents achieved, in both markets, by producing new products that, in the short run, had no competition.

- indeed, the largest profits to be made was from successful innovations and marketing new products, convincing consumers, at home and abroad, of the necessity of acquiring them
- and to do before rivals created competing substitutes: so that initially the innovating firms could charge very high prices, which competition would subsequently force down
- consider, as a modern example: the development of and innovations in modern computer products, with initially very high prices, followed by steep falls in prices as competitive markets are marketed.[19]

iv) **We have already considered Webb's thesis on cartels and vertical integration in the German steel industry:**

(1) That vertical integration encouraged much larger scale and much more extensive mechanization at each stage (with very large fuel economies);

(2) and that in turn promoted greater efficiency and lower cost production.

(3) Both Webb and Allan indicate that the German steel industry, at least that section devoted to cheaper bulk steels, was the most efficient and productive in the world.

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market dominating firms that are responsible for key innovations (though not uniquely so, of course).

[19] As an example: in 1995 I purchased my first laptop computer with a colour monitor, the only one then available with colour: an IBM Thinkpad, which cost me (before taxes) $7,500 (purchased from my research grant). It is worth noting that in Dec. 1995, the Canadian CPI (base: 2002 = 100), was 87.80, compared to 117.50 in Dec. 2010, i.e., 33.82% higher. Thus in terms of the value of the dollar in late 2010, that would be $10,036.50. This 1995 IBM computer had no software installed, not even Windows (then Windows 3.1). Today one could buy a far better computer, with not only Windows 7, far more RAM and hard disk capacity, etc., and other software installed for about $500.00. Staples advertizes a Compaq 15.6" Laptop, 2.2GHz AMD Athlon II X2, 4GB RAM, 360GB HDD: for $479.50 plus taxes, and thus under 5% of the real price that I paid for my IBM Thinkpad in 1995.

(4) Even if the German steel industry did practise price-discrimination, by and large its steel products were cheaper in the domestic market than British steels were in the British home market (as just noted, above).

f) **Summary Comments on German Industrialisation:**

i) **Thanks to the recent research of two German historians,** we now have adequate and extremely useful statistics on the growth of the German economy, and its industrial sector in particular, from 1851 to 1913

ii) **From their data (over two different articles),** I have provided, on the screen (and appendix), a summary of their statistical findings, presented in quinquennial means (5 years), with values expressed either as:[20]

(1) constant German marks, based on the value of the mark in 1913

(2) Index numbers, with the base 100 = value for 1913

iii) **note the following:**

(1) Net National Product, in real terms, grew by 316.9%, from the mean of 1851-55 to 1911-13: i.e., from 12.42 billion marks to 51.78 billion marks, without any hiatus in the growth of NNP

(2) Net industrial investment grew 2108.5% over the same period: from 68.60 billion to 1,515.00 billion marks

(3) Income per employee in the modern growth sector about doubled: from 1,113 marks to 2,265

(4) but capital stock per industrial employee grew by 277.2%: from 2,562 marks to 9,663 marks

(5) The industrial productivity index grew by two-thirds (66.67%): from 0.60 to 1.00 (1913 index)

(6) The Industrial production index grew by 482.75%: from 17.16 to 100.00 (mean of 1911-13 = 97.20)

(7) Indirect taxes grew by 1,075.1%: from 240.60 million marks to 2,827.33 million marks

iv) **Obviously it would be difficult to argue from these data that:** either cartels and/or the investment banks hindered German economic and industrial development.

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[20] Carsten Burhop and Guntram B. Wolff, ‘A Compromise Estimate of German Net National Product, 18151-1913, and Its Implications for Growth and Business Cycles, *Journal of Economic History*, 65:3 (September 2005), 613-57; Carsten Burhop, ‘Did Banks Cause the German Industrialization?’, *Explorations in Economic History*, 43:1 (January 2006), 39-63.

Appendix I: on IG Farben and the German Chemicals Industries

I.G. Farbenindustrie AG IG Farben Logo 001.svg

Former type Public
Industry Chemicals
Fate Liquidated
Predecessor(s) BASF, Bayer, Hoechst, Agfa, Griesheim-Elektron, Weiler Ter Meer
Successor(s) BASF, Bayer, Hoechst
Founded December 25, 1925
Defunct 1952
Headquarters Frankfurt am Main

IG Farben was a German chemical industry conglomerate. Its name is taken from Interessen-Gemeinschaft Farbenindustrie AG (Syndicate [literally, "community of interests"] of dye-making corporations). The company was formed in 1925 from a number of major chemical companies that had been working together closely since World War I. During its heyday IG Farben was the largest chemical company in the world and the fourth largest overall industrial concern, after General Motors, U.S. Steel and Standard Oil (New Jersey).

IG Farben was involved in numerous war crimes during World War II. It was seized by the Allies in 1945 and liquidated in 1952. It still nominally exists as an asset-less shell, with the stated goal of paying restitution to the victims of its many crimes in the form of compensation and reparations.
Contents

Founding members

IG Farben was founded on December 25, 1925, as a merger of the following six companies:[1]

- BASF
- Bayer
- Hoechst (including Cassella and Chemische Fabrik Kalle)
- Agfa
- Chemische Fabrik Griesheim-Elektron
- Chemische Fabrik vorm. Weiler Ter Meer

History

Predecessors of IG Farben

At the beginning of the 20th century the German chemical industry dominated the world market for synthetic dyes. The three major firms BASF, Bayer and Hoechst produced several hundred different dyes, along with the five smaller firms Agfa, Cassella, Chemische Fabrik Kalle, Chemische Fabrik Griesheim-Elektron and Chemische Fabrik vorm. Weiler-ter Meer concentrated on high-quality specialty dyes. In 1913 these eight firms produced almost 90 percent of the world supply of dyestuffs and sold about 80 percent of their production abroad.[2] The three major firms had also integrated upstream into the production of essential raw materials and they began to expand into other areas of chemistry such as pharmaceuticals, photographic film, agricultural chemicals and electrochemicals. Contrary to other industries the founders and their families had little influence on the top-level decision-making of the leading German chemical firms, which was in the hands of professional salaried managers. Because of this unique situation the economic historian Alfred Chandler called the German dye companies "the world's first truly managerial industrial enterprises".[3]

With the world market for synthetic dyes and other chemical products dominated by the German industry, German firms competed vigorously for market shares. Although cartels were attempted they lasted at most for a few years. Others argued for the formation of a profit pool or Interessen-Gemeinschaft (abbr. IG, lit. Community of interest).[4] In contrast, the chairman of Bayer, Carl Duisberg, argued for a merger. During a trip to the United States in the spring of 1903 he had visited several of the large American trusts such as Standard Oil, U.S. Steel, International Paper and Alcoa.[5] In 1904, after having returned to Germany he proposed a nationwide merger of the producers of dye and pharmaceuticals in a memorandum to Gustav von Brüning, the senior manager at Hoechst.[6] Hoechst and several pharmaceutical firms refused to join. Instead, Hoechst and Cassella made an alliance based on mutual equity stakes in 1904. This prompted Duisberg and Heinrich von Brunck, chairman of BASF, to accelerate their negotiations. In October 1904 an Interessen-Gemeinschaft between Bayer, BASF and Agfa was formed, also known as the Dreibund or little IG. Profits of the three firms were pooled, with BASF and Bayer getting 43 percent and Agfa 14 percent of all profits.[7] The two alliances were loosely connected with each other through an agreement between BASF and Hoechst to jointly exploit the patent on the Heumann-Pfleger indigo synthesis.[8]

Within the Dreibund Bayer and BASF concentrated on dye whereas Agfa increasingly concentrated on photographic film. Although there was some cooperation between the technical staff in production and accounting, there was little cooperation between the firms in other areas. Neither were production or distribution facilities consolidated nor did the commercial staff cooperate.[9] In 1908 Hoechst and Cassella acquired 88 percent of the shares of Chemische Fabrik Kalle. As Hoechst, Cassella and Kalle were connected by mutual equity shares and were located close to each other in the Frankfurt area, this allowed them to cooperate more successfully than the Dreibund, although they also did not rationalize or consolidate their production facilities.[9]
Foundation of IG Farben

IG Farben was founded on December 25, 1925 as a merger of the following six companies: BASF (27.4 percent of equity capital), Bayer (27.4 percent), Hoechst including Cassella and Chemische Fabrik Kalle (27.4 percent), Agfa (9.0 percent), Chemische Fabrik Griesheim-Elektron (6.9 percent) and Chemische Fabrik vorm. Weiler Ter Meer (1.9 percent). In 1926 IG Farben had a market capitalization of 1.4 billion Reichsmark and a workforce of 100,000 people, of which 2.6 percent were university educated, 18.2 percent were salaried professionals and 79.2 percent were workers.[1] BASF was the nominal survivor; all shares were exchanged for BASF shares.

Similar mergers took place in other countries. In the United Kingdom Brunner Mond, Nobel Industries, United Alkali Company and British Dyestuffs merged to form Imperial Chemical Industries in September 1926. In France Établissements Poulenc Frères and Société Chimique des Usines du Rhône merged to form Rhône-Poulenc in 1928.[10]

The IG Farben Building, headquarters for the conglomerate in Frankfurt am Main, Germany, was completed in 1931.

World War II overview

During the planning of the occupation of Czechoslovakia and the invasion of Poland, IG Farben cooperated closely with Nazi officials and directed which chemical plants should be secured and delivered to IG Farben.[12]

In 1941, an investigation exposed a "marriage" cartel between John D. Rockefeller's United States-based Standard Oil Co. and I.G. Farben.[13][14][15][16] It also brought new evidence concerning complex price and marketing agreements between DuPont, a major investor in and producer of leaded gasoline, United States Industrial Alcohol Company and its subsidiary, Cuba Distilling Co. The investigation was eventually dropped, like dozens of others in many different kinds of industries, due to the need to enlist industry support in the war effort.[citation needed] However, the top directors of many oil companies agreed to resign, and oil industry stocks in molasses companies were sold off as part of a compromise worked out.[17][18][19]

Zyklon B labels

IG Farben held the patent for the pesticide Zyklon B[20] (used in Holocaust gas chambers), and owned 42.2 percent (in shares) of Degesch (Deutsche Gesellschaft für Schädlingsbekämpfung) which manufactured it. IG Farben also had managers in Degesch's Managing Committee. Of the 24 directors of IG Farben indicted in the so-called IG Farben Trial (1947–1948) before a U.S. military tribunal at the subsequent Nuremberg Trials, 13 were sentenced to prison terms between one and eight years. Some of those indicted in the trial were subsequently made leaders of the post-war companies that split off from IG Farben, including those who were sentenced at Nuremberg.[citation needed]

Some of the people who served prison sentences but later became leaders in post war-companies include:

Hermann Schmitz, who became a member of the supervisory board for the Deutsche Bank in Berlin and honorary chairman of the supervisory board of Rheinische Stahlwerke AG [21]

Georg von Schnitzler, serving as president of the Deutsch-Ibero-Amerikanische Gesellschaft [22]

Fritz ter Meer, becoming chairman of the supervisory board of Bayer AG and a supervisory board member of several firms [23]

Otto Ambros, holding seats on supervisory boards Chemie Grünenthal (being active during the Contergan scandal), Feldmühle, and Telefunken, and working as an economic consultant in Mannheim [24]

Heinrich Bütefisch, becoming a member of the supervisory boards for Deutsche Gasolin AG, Feldmühle, and Papier- und Zellstoffwerke AG, and consulting with Ruhrchemie AG Oberhausen and subsequently joining its supervisory board.[25]

Max Ilgner, becoming the chairman of the executive board of a chemistry firm in Zug [26]

Heinrich Oster, becoming a member of the supervisory board of Gelsenberg AG.[27]

Some of the people who were acquitted and later became leaders in post war-companies include:

Fritz Gajewski, becoming chairman of the board of Dynamit Nobel.[28]

Christian Schneider (chemist), becoming a member of the supervisory boards of Süddeutsche Kalkstickstoff-Werke AG Trostberg and Rheinauer Holzhydrolyse-GmbH, Mannheim [29]

Hans Kühne, taking a position at Bayer Elberfeld.[30]

Carl Lautenschläger, becoming a research associate at Bayer Elberfeld.[31]

Wilhelm Rudolf Mann, resuming his position as head of pharmaceutical sales at Bayer. He also presided over the GfK, Society for Consumer Research, and the Foreign Trade Committee of the BDI, Federation of German Industry.[32]

Carl Wurster, resuming his position of chairman of the managing board, and was the major force behind the reestablishment of BASF. After retiring, he continued to be active as a member and chairman of supervisory boards in companies such as Bosch, Degussa (later being acquired by RAG [33]), and Allianz.[34]

Heinrich Gattineau, becoming a member of the board and supervisory council of WASAG Chemie-AG, and Mitteldeutsche Sprengstoff-Werke GmbH [35]

IG Farben facilities were bombing targets of the Oil Campaign of World War II, and up to 1941, there were 5 Nazi Germany Buna plants that produced Buna N by the Lebedev process.[36]:15

Dwory

The Buna Chemical Plant at Dwory was under construction by 1943,[37] after a March 2, 1942 contract with "IG Farbenindustrie AG Auschwitz."[38] The Buna Werke plant, which produced synthetic oil and rubber (from coal), was the beginning of SS activity and camps near Auschwitz III-Monowitz during the Holocaust.[citation needed] At its peak in 1944, this factory made use of 83,000 slave laborers.[39] Today, the plant operates as "Dwory S.A." [40]

Frankfurt

In addition to the "cavernous" IG Farben building at Frankfurt, a Hoechst AG chemical factory in Frankfurt was bombed by the RAF on September 26, 1944.

Ludwigshafen and Oppau

The I.G. Farbenindustrie, A. G., Works, Ludwigshafen and Oppau had several chemical plants.

Pölitz, North Germany (today Police, Poland)

In 1937, IG Farben, Rhenania-Ossag, and Deutsch-Amerikanische Petroleum Gesellschaft founded the Hydrierwerke Pölitz AG synthetic fuel plant.[41]:193ff By 1943, the plant produced 15% of Nazi Germany's synthetic fuels, 577,000 tons.[41]:196

Waldenburg

An IG Farben plant was at Waldenburg[42]:6

Break-up and liquidation

Due to the severity of the war crimes committed by IG Farben during World War II, the company was considered to be too corrupt to be allowed to continue to exist. The Soviet Union seized most of IG Farben's assets located in the Soviet occupation zone (see Morgenthau Plan), as part of their reparation payments. The Western Allies however, in 1951, split the company up into its original constituent companies. The four largest quickly bought the smaller ones. Today Agfa, BASF, and Bayer remain, Hoechst having in 1999 demerged its industrial chemical operations to Celanese AG and merged its life-sciences businesses with Rhône-Poulenc's to form Aventis.

Part of Hoechst was afterwards Celanese AG, while another part of the company was sold in 1997 to the chemical spin-off of Sandoz, the Muttenz (Switzerland) based Clariant.

IG Farben was officially put into liquidation in 1952, but this did not end the company's legal existence. As of 2012, it still exists as a corporation "in liquidation", meaning that the purpose of the continuing existence of the corporation is being wound up and dissolved in an orderly fashion. As of 2012, its shares are still traded on German markets.[43]

In 2001, IG Farben announced it would formally wind up its affairs in 2003. It has been continually criticized over the years for failing to pay any compensation to the former laborers, which was the stated reason for its continued existence after 1952. The company, in turn, blamed ongoing legal disputes with the former captive labourers as being the reason it could not be legally dissolved and the remaining assets distributed as reparations.[44] On November 10, 2003, its liquidators filed for insolvency,[45] but again, this does not affect the existence of the company as a legal person. While it did not join a national compensation fund set up in 2001 to pay the victims, it contributed 500,000 DM (£160,000 or €255,646) towards a foundation for former captive labourers under the Nazi regime. The remaining property, worth DM 21 million (£6.7 million or €10.7 million), went to a buyer.[46] Each year, the company's annual meeting in Frankfurt is the site of demonstrations by hundreds of protesters.[44]

IG Farben Trial

The United States of America vs. Carl Krauch, et al., also known as the IG Farben Trial, was the sixth of the twelve trials for war crimes the U.S. authorities held in their occupation zone in Germany (Nuremberg) after the end of World War II, against leading industrialists of Nazi Germany for their conduct during the Nazi regime. The defendants in this case had all been directors of IG Farben. Of the 24 defendants arraigned, 13 were found guilty. The indictment was filed on May 3, 1947; the trial lasted from August 27, 1947 until July 30, 1948.

All defendants who were sentenced to prison received early release. Most were quickly restored to their directorships, and some were awarded the Federal Cross of Merit.[47]

Patents and scientific knowledge

Once Germany surrendered, the US moved quickly to commercially exploit German patents and scientific knowledge. (see Industrial plans for Germany)

Konrad Adenauer stated "According to a statement made by an American expert, the patents formerly belonging to IG Farben have given the American chemical industry a lead of at least 10 years. The damage thus caused to the German economy is huge and cannot be assessed in figures. It is extraordinarily regrettable that the new German inventions cannot be protected either, because Germany is not a member of the Patent Union. Britain has declared that it will respect German inventions regardless of what the peace treaty may say. But America has refused to issue such a declaration. German inventors are therefore not in a position to exploit their own inventions. This puts a considerable brake on German economic development."[48]

Products

Synthetic dyes, Nitrile rubber, Polyurethane, Prontosil, Resochin, Zyklon B, among others.

IG Farben scientists made fundamental contributions to all areas of chemistry. Otto Bayer discovered the polyaddition for the synthesis of polyurethane in 1937.[49] Several IG Farben scientists were awarded a Nobel Prize. Carl Bosch and Friedrich Bergius were awarded the Nobel Prize in Chemistry in 1931 "in recognition of their contributions to the invention and development of chemical high pressure methods".[50] Gerhard Domagk was awarded the Nobel Prize in Physiology or Medicine in 1939 "for the discovery of the antibacterial effects of prontosil".[51] Kurt Alder was awarded the Nobel Prize in Chemistry (together with Otto Diels) in 1950 "for his [their] discovery and development of the diene synthesis".[52]

Appendix II: on the Telephone and Alexander Graham Bell

Scottish-born American inventor and teacher of the deaf, Alexander Graham Bell (1847-1922) is best known for perfecting the telephone to transmit vocal messages by electricity. The telephone inaugurated a new age in communication technology.

Alexander Graham Bell was born on March 3, 1847, in Edinburgh. His father, Alexander Melville Bell, was an expert in vocal physiology and elocution; his grandfather, Alexander Bell, was an elocution professor.

After studying at the University of Edinburgh and University College, London, Bell became his father's assistant. He taught the deaf to talk by adopting his father's system of visible speech (illustrations of speaking positions of the lips and tongue). In London he studied Hermann Ludwig von Helmholtz's experiments with tuning forks and magnets to produce complex sounds. In 1865 Bell made scientific studies of the resonance of the mouth while speaking.

In 1870 the Bells moved to Brantford, Ontario, Canada, to preserve Alexander's health. He went to Boston in 1871 to teach at Sarah Fuller's School for the Deaf, the first such school in the world. He also tutored private students, including Helen Keller. As professor of vocal physiology and speech at Boston University in 1873, he initiated conventions for teachers of the deaf. Throughout his life he continued to educate the deaf, and he founded the American Association to Promote the Teaching of Speech to the Deaf.

From 1873 to 1876 Bell experimented with a phonautograph, a multiple telegraph, and an electric speaking telegraph (the telephone). Funds came from the fathers of two of his pupils; one of these men, Gardiner Hubbard, had a deaf daughter, Mabel, who later became Bell's wife.

Inventing the Telephone

To help deaf children, Bell experimented in the summer of 1874 with a human ear and attached bones, a tympanum, magnets, and smoked glass. He conceived the theory of the telephone: an electric current can be made to change intensity precisely as air density varies during sound production. Unlike the telegraph's use of intermittent current, the telephone requires continuous current with varying intensity. That same year he invented a harmonic telegraph, to transmit several messages simultaneously over one wire, and a telephonic-telegraphic receiver. Trying to reproduce the human voice electrically, he became expert with electric wave transmission.

Bell supplied the ideas; Thomas Watson made and assembled the equipment. Working with tuned reeds and magnets to synchronize a receiving instrument with a sender, they transmitted a musical note on June 2, 1875. Bell's telephone receiver and transmitter were identical: a thin disk in front of an electromagnet.

On Feb. 14, 1876, Bell's attorney filed for a patent. The exact hour was not recorded, but on that same day Elisha Gray filed his caveat (intention to invent) for a telephone. The U.S. Patent Office granted Bell the patent for the "electric speaking telephone" on March 7. It was the most valuable single patent ever issued, and it opened a new age in communication technology.

Bell continued his experiments to improve the telephone's quality. By accident, Bell sent the first sentence, "Watson, come here; I want you, " on March 10, 1876. The first demonstration occurred at the American Academy of Arts and Sciences convention in Boston 2 months later. Bell's display at the Philadelphia Centennial Exposition a month later gained more publicity, and Emperor Dom Pedro of Brazil ordered 100 telephones for his country. The telephone, accorded only 18 words in the official catalog of the exposition, suddenly became the "star" attraction.

Establishing an Industry

Repeated demonstrations overcame public skepticism. The first reciprocal outdoor conversation was between Boston and Cambridge, Mass., by Bell and Watson on Oct. 9, 1876. In 1877 the first telephone was installed in a private home; a conversation was conducted between Boston and New York, using telegraph lines; in May, the first switchboard, devised by E. T. Holmes in Boston, was a burglar alarm connecting five banks; and in July the first organization to commercialize the invention, the Bell Telephone Company, was formed. That year, while on his honeymoon, Bell introduced the telephone to England and France.

The first commercial switchboard was set up in New Haven, Conn., in 1878, and Bell's first subsidiary, the New England Telephone Company, was organized that year. Switchboards were improved by Charles Scribner, with more than 500 inventions. Thomas Cornish, a Philadelphia electrician, had a switchboard for eight customers and published a one-page directory in 1878.

Contesting Bell's Patent

Other inventors had been at work. Between 1867 and 1873 Professor Elisha Gray (of Oberlin College) invented an "automatic self-adjusting telegraph relay, " installed it in hotels, and made telegraph printers and repeaters. He tried to perfect a speaking telephone from his harmonic (multiple-current) telegraph. The Gray and Batton Manufacturing Company of Chicago developed into the Western Electric Company.

Another competitor was Professor Amos E. Dolbear, who insisted that Bell's telephone was only an improvement on an 1860 invention by Johann Reis, a German, who had experimented with pigs' ear membranes and may have made a telephone. Dolbear's own instrument, operating by "make and break" current, could transmit pitch but not voice quality.

In 1879 Western Union, with its American Speaking Telephone Company, ignored Bell's patents and hired Thomas Edison, along with Dolbear and Gray, as inventors and improvers. Later that year Bell and Western Union formed a joint company, with the latter getting 20 percent for providing wires, circuits, and equipment. Theodore Vail, organizer of Bell Telephone Company, consolidated six companies in 1881. The modern transmitter evolved mainly from the work of Emile Berliner and Edison in 1877 and Francis Blake in 1878. Blake's transmitter was later sold to Bell for stock.

The claims of other inventors were contested. Daniel Drawbaugh, from rural Pennsylvania, with little formal schooling, almost won a legal battle with Bell in 1884 but was defeated by a 4 to 3 vote in the Supreme Court. The claim by this "Edison of the Cumberland Valley" was the most exciting (and futile) litigation over telephone patents. Altogether, the Bell Company was involved in 587 lawsuits, of which 5 went to the Supreme Court; Bell won every case. A convincing argument was that no competitor claimed originality until 17 months after Bell's patent. Also, at the 1876 Philadelphia Exposition, eminent electrical scientists, especially Lord Kelvin, the world's foremost authority, had declared it to be "new." Professors, scientists, and researchers defended Bell, pointing to his lifelong study of the ear and his books and lectures on speech mechanics.

The Bell Company

The Bell Company built the first long-distance line in 1884, connecting Boston and New York. The American

Telephone and Telegraph Company was organized by Bell and others in 1885 to operate other long-distance lines. By 1889, when insulation was perfected, there were 11, 000 miles of underground wires in New York City.

The Volta Laboratory was started by Bell in Washington, D.C., with the Volta Prize money (50, 000 francs, about $10, 000) awarded by France for his invention. At the laboratory he and associates worked on various projects during the 1880s, including the photophone, induction balance, audiometer, and phonograph improvements. The photophone transmitted speech by light, using a primitive photoelectric cell. The induction balance (electric probe) located metal in the body. The audiometer indicated Bell's continued interest in deafness. The first successful phonograph record, a shellac cylinder, as well as wax disks and cylinders, was produced. The Columbia Gramophone Company exploited Bell's phonograph records. With the profits Bell established the Volta Bureau in Washington to study deafness.

Bell's Later Interests

Other activities took much time. The magazine Science (later the official organ of the American Association for the Advancement of Science) was founded in 1880 because of Bell's efforts. He made numerous addresses and published many monographs. As National Geographic Society president from 1896 to 1904, he fostered the success of the society and its publications. In 1898 he became a regent of the Smithsonian Institution. He was also involved in sheep breeding, hydrodynamics, and aviation projects.

Aviation was Bell's primary interest after 1895. He aided Samuel Langley, invented the tetrahedral kite (1903), and founded the Aerial Experiment Association (1907), bringing together Glenn Curtiss, Francis Baldwin, and others. They devised the aileron control principle (which replaced "wing warping"), developed the hydroplane, and solved balance problems in flying machines. Curtiss furnished the motor for Bell's man-carrying kite in 1907.

Bell died at Baddeck, Nova Scotia, on Aug. 2, 1922.

Further Reading

Catherine D. MacKenzie, Alexander Graham Bell (1928), is interesting and contains much personal information. Thomas Bertram Costain, Chord of Steel (1960), a recent history of the telephone, discusses Bell at length. Herbert Casson, The History of the Telephone (1910), is still useful for the early story. See also Arthur Pound, The Telephone Idea: Fifty Years After (1926), and Frederick Leland Rhodes, Beginnings of Telephony (1929). For the story of Bell's persistent rival see Warren J. Harder, Daniel Drawbaugh (1960).

Table 1. Output of Coal in Millions of Metric Tons:

For Selected European Countries, Decennial Means: 1820/9 - 1910/3

Decade	Great Britain	Belgium	France	Germany	Russia
1820-9	20.00	n.a.	1.30	1.40	n.a.
1830-9	25.45	2.75	2.45	2.45	n.a.
1840-9	40.40	4.60	3.95	5.25	n.a
1850-9	59.00	7.70	6.45	11.95	n.a
1860-9	95.50	11.35	11.35	25.90	0.45
1870-9	129.45	14.70	16.20	45.65[a]	1.60
1880-9	163.40	17.95	20.85	71.90[b]	4.35
1890-9	194.15	20.70	28.45	107.05[c]	9.05
1900-9	245.30	24.05	34.70	179.25[d]	20.50
1910-3	275.40	24.80	39.90	247.50[e]	30.20

Germany: proportion of total coal output accounted for by lignite:

a. in 1871 22.4%

b. in 1880 20.5%

c. in 1890 21.4%

d. in 1900 27.0%

e. in 1910 31.3%

1 metric tonne = 1000 kilograms = 2,204.6 lb.

Source: Carlo Cipolla, ed., *Fontana Economic History of Europe*, Vol. IV:2, p. 770.

Table 2a. **Decennial Averages of the Output of Pig Iron and Steel in France, Germany, Russia, and the United Kingdom, in millions of metric tons,**

1830-9 to 1910-3 (iron) and 1870-9 to 1910-3 (steel)

Average of 1880-9 = 100. 1 metric ton = 1000 kg. = 2,204.6 lb.

Decade	France	Index	GERMANY	Index	Russia	Index	UK	Index
IRON								
1830-9	0.286	16	0.129	4	0.172	31	0.921	11
1840-9	0.442	25	0.172	5	0.192	35	1.625	20
1850-9	0.731	25	0.334	5	0.243	44	3.150	39
1860-9	1.164	66	0.813	25	0.304	56	4.602	57
1870-9	1.337	75	1.678	52	0.400	73	6.648	81
1880-9	1.772	100	3.217	100	0.547	100	8.040	100
1890-9	2.192	124	5.155	160	1.539	281	8.090	101
1900-9	3.028	171	9.296	289	2.786	509	9.317	116
1910-13	4.664	263	14.836	461	3.870	707	9.792	122
STEEL								
1870-9	??	52			??	33	0.695	30
1880-9	0.500	100	1.320	100	0.240	100	2.340	100
1890-9	1.015	203	3.985	302	0.930	388	3.760	161
1900-9	2.175	435	9.505	720	2.490	1038	5.565	238
1910-13	4.090	818	16.240	1230	4.200	1750	6.930	296

*1875-9 only.

Table 2b.

World steel production, 1865 - 1910

in Thousands of Metric Tons (2,204.6 lb.)

Year	Britain	Germany	U.S.	WORLD
1865	225		100	
1870	286	169	68	703
1880	1,320	660	1,267	4,273
1890	3,637	2,161	4,346	12,096
1900	5,130	6,645	10,382	28,727
1910	6,374	13,698	26,512	58,656

Table 3

International Comparisons in Steel Production, 1906-1913
Price and Costs of Steel Production in Germany, U.S., and Great Britain

A. McCloskey on British-American Productivity Differences				
Steel Product (1907-09)		**British Advantage**		**American Advantage**
Heavy Plates		1.57%		
Rails				8.13%
Bars, Rods				7.22%
Structural Steel				5.94%
Blank Plates, Sheets		1.85%		
B. German & American Production Costs as percent of British production costs in 1913				
Input		**German (1906-13)**		**American (1910-13)**
Iron Ore		69.0%		97.0%
Fuel		88.0%		65.0%
Scrap Metal		95.0%		99.0%
Labour		72.0%		170.0%
Average Unit Costs		**72.0%**		**90.0%**
Total Factor Productivity (gains)		**115.0%**		**115.0%**

C. Steel Prices, in Shillings Sterling per Metric Ton: mean of 1906-13 = 100				
Steel Product	**German Domestic**	**German Export**	**American Domestic**	**British Domestic**
Steel Rails	n.a.	110	115	121
Steel Bars	106	106	127	139
Heavy Plates	124	119	132	139
Stuctural Steel	114	107	133	130
D. German & American Steel Prices as percentages of British Prices				
Steel Product	**German Domestic**	**German Export**	**American Domestic**	
Steel Rails	n.a.	90.9%	95.0%	
Steel Bars	76.3%	76.3%	91.4%	
Heavy Plates	89.2%	85.6%	95.0%	
Structural Steel	87.7%	82.3%	102.3%	

Sources:

Donald McCloskey, ‘International Differences in Productivity? Coal and Steel in America and Britain Before World War I’, in D.N. McCloskey, ed., *Essays on a Mature Economy: Britain After 1840* (Princeton, 1971), pp. 215-34.

Robert Allen, ‘International Competition in Iron and Steel, 1850-1913', *Journal of Economic History*, 39 (Dec. 1979), pp. 911-38.

Steven Webb, ‘Tariffs, Cartels, Technology, and Growth in the German Steel Industry, 1879 to 1914’, *Journal of Economic History*, 40 (June 1980), 309-30.

Table 4. **Aggregate and Per Capita Indices of Industrial Production (United Kingdom in 1900 = 100), and percentage shares of world industrial production, for various countries: in 1860 and 1913**

Country	Total Industrial Output		Per Capita Industrial Output	Percentage Shares of World Industrial Production		
With 1913 Frontiers	**1860**	**1913**	**1860**	**1913**	**1860**	**1913**
	Index	**Index**	**Index**	**Index**	**%**	**%**
United Kingdom*	45	127	64	115	20%	14%
Germany	11	138	15	85	5%	15%
France	18	57	20	59	8%	6%
Russia	16	77	8	20	7%	8%
ALL EUROPE	**120**	**528**	**17**	**45**	**53%**	**57%**
United States	16	298	21	126	7%	32%
Canada	1	9	7	46	--	1%

Source: Paul Bairoch, 'International Industrialization Levels from 1760 to 1980', *Journal of European Economic History*, 11 (Fall 1982), 269-333, tables 4 - 13.

* The United Kingdom of Great Britain and Ireland: the values for its aggregate and per capita industrial outputs for 1900 are taken as the base 100 for all the indices in columns 1 to 4. Note that columns 5 and 6 are percentages of total world industrial output.

Table 5. **Indices of Industrial Output*: in the United Kingdom, France, Germany, and the United States in quinquennial means, 1860-4 to 1910-13**
Mean of 1870-4 = 100

Period	**United Kingdom**	**France**	**Germany**	**United States**
1860-64	72.6			
1865-69	82.8	95.8	72.6	75.5
1870-74	100.0	100.0	100.0	100.0
1875-79	105.5	109.5	120.8	111.4
1880-84	123.4	126.6	160.6	170.4
1885-89	129.5	130.3	194.9	214.9
1890-94	144.2	151.5	240.6	266.4
1895-99	167.4	167.8	306.4	314.2
1900-04	181.1	176.1	354.3	445.7
1905-09	201.1	206.2	437.4	570.0
1910-13	219.5	250.2	539.5	674.9

* Excluding construction, but including building materials.

Source: W. Arthur Lewis, *Growth and Fluctuations, 1870 - 1913* (London, 1978), pp. 248-50, 269, 271, 273.

Table 6. Per Capita Product in Selected European Countries, 1850 - 1910: Measured in Constant 1970 U.S. Dollars

COUNTRY	1850	1870	1890	1910	Percent-age Total Growth 1850-1910
BRITAIN	660	904	1,130	1,302	197%
FRANCE	432	567	668	883	204%
GERMANY	418	579	729	958	229%
BELGIUM	534	738	932	1,110	208%
NETHER-LANDS	481	591	768	952	198%

Source: Nicholas Crafts, 'Gross National Product in Europe, 1870 - 1910: Some New Estimates', *Explorations in Economic History*, 20 (October 1983), 387-401.

Table 7. Net Capital Formation (Domestic and Foreign) as a percentage of Net National Product in Germany and the U.K.: 1860-1910

Decade	**Germany**	**U.K.**	**U.K.**
	(Mitchell	**(Kuznets**	**(Feinstein**
	1975)	**1961)**	**1976)**
1860-9	11.9%	10.0%	-
1870-9	12.1%	11.8%	8.9%
1880-9	11.1%	10.9%	8.1%
1890-9	13.6%	10.1%	7.5%
1900-9	14.4%	11.7%	9.5%

Table 8. **FOREIGN TRADE STATISTICS**

Current Values and Indices of the Domestic Exports of the United Kingdom, France, and Germany: quinquennial means, 1860-4 to 1910-13

Mean of 1870-74 = 100

Period	**United Kingdom** Domestic Exports in Millions	**U.K.** Index 1870-4 = 100	**France** Exports in Millions of Francs	**France** Index 1870-4 = 100	**Germany** Exports in Millions of Marks	**Germany** Index 1870-4 = 100
1860-4	138.4	58.9	2,402.6	71.0		
1865-9	181.1	77.1	2,992.0	88.4		
1870-4	234.8	100.0	3,385.0	100.0	2,328.4*	100.0
1875-9	201.5	85.8	3,459.2	102.2	2,696.1*	115.8
1880-4	234.3	99.8	3,457.4	102.1	3,125.0	134.2
1885-9	226.2	96.3	3,306.8	97.7	3,067.4	131.7
1890-4	234.4	99.8	3,419.6	101.0	3,102.0	133.2
1895-9	239.7	102.1	3,607.4	106.6	3,688.4	158.4
1900-4	289.2	123.2	4,215.4	124.5	4,791.6	205.8
1905-9	377.3	160.7	5,191.4	153.4	6,386.0	274.3
1910-3	474.2	202.0	6,476.0	191.3	8,658.8	371.9

* estimated

Source: B.R. Mitchell, 'Statistical Appendix', in Carlo Cipolla, ed., *Fontana Economic History of Europe*, Vol. IV:2, *Emergence of Industrial Societies* (1973), pp. 798-800.

Table 9. German Industrial Cartels:

The Major Cartels:

1876	The German Rail Federation [for steel]
1879	Pig Iron Syndicate (evolving into the All-German Pig Iron Syndicate by 1896)
1888	Potash Syndicate (enlarged by government edict in 1910)
1893	The Rhine-Westphalian Coal syndicate (absorbing regional cartels)
1904	German Steelworks Association (Deutsche Stahlwerksverband, absorbing 27 earlier regional cartels)

German cartels functioning in 1905:

Industry	**Number of Cartels in the Industry**
Iron and Steel	62
Coal	19
Non-ferrous metals	11
Chemicals	46
Textiles	31
Glass	10
Electrical	2
Food and Drink	17
Paper	6
Leather and Rubbergoods	6
Timber	5
Quarrying	27
Bricks	132 [all regional cartels]

Industrial Employment in Germany in 1913

Chemicals	290,000
Metallurgy	443,000
Coal Mining	728,000
Textiles	1,100,000

Table 10. **Comparison of Businessmen in Germany and Great Britain 1890 - 1910: in terms of Science and Education**

Characteristics of Businessmen	Germany	Great Britain
Attending Schools: Gymnasium/Grammar	59%	30%
Businessmen Attending University	24%	13%
University Students enrolled	60,000	9,000
Populations 1910	65 million	41 million
State Funding of Science and Technology	12.3 million marks	2.0 million marks
Businessmen who studied science & technology	61%	(very small)?
Business Managers with university degrees	65%	n.a.?
Salaried managers	28%	7%
Businessmen who had lived and worked outside country	72%	22%
Peerages granted to Businessmen	11%	36%
Businessmen with political affiliations	4%	46%

Source: Hartmut Berghoff and Roland Möller, ‘Tired Pioneers and Dynamic Newcomers? A Comparative Essay on English and German Entrepreneurial History, 1870 - 1914', *Economic History Review*, 2nd ser., 47:2 (May 1994), 262-87.

Table 11. **Components of German Industrialization**

1851-55 to 1910-13: in quinquennial averages, with 1913 marks

Year	NNP in 1913 marks billions	Net Industrial Investment 1913 marks millions	Industrial Capital Stock 1913 marks billions	Indirect Taxes 1913 marks millions	Income per Employee 1913 Marks	Capital Stock per Employee 1913 Marks	Productivity Level 1913=1.00	Industrial Production Index 1913=100	Return on Industrial Capital Percent
1851-55	12.42	68.60	6.00	240.60	1,113	2,562	0.60	17.16	7.06
1856-60	13.76	68.20	6.15	292.60	1,167	2,638	0.63	19.34	6.44
1861-65	15.59	195.00	6.96	355.60	1,244	2,890	0.66	22.50	10.10
1866-70	16.76	165.00	7.88	433.20	1,317	3,213	0.69	25.62	10.94
1871-75	18.38	469.00	9.42	526.80	1,588	3,839	0.81	33.08	12.80
1876-80	20.49	94.00	11.09	640.80	1,569	4,662	0.77	34.52	5.86
1881-85	22.91	568.60	12.44	779.80	1,532	5,001	0.75	36.36	7.58
1886-90	26.68	1,016.60	16.67	948.60	1,556	5,146	0.75	43.36	9.40
1891-95	30.16	847.20	21.74	1153.80	1,728	5,754	0.82	52.20	9.06
1896-1900	35.58	2,017.80	28.37	1404.00	1,801	6,360	0.84	61.88	12.58
1901-05	39.76	1,769.40	39.49	1659.60	1,886	7,626	0.85	69.26	10.14
1906-10	45.91	2,558.80	49.90	2208.40	2,080	8,761	0.92	83.16	11.84
1911-13	51.78	1,515.00	58.66	2,827.33	2,265	9,663	0.99	97.20	12.67

Sources:

Carsten Burhop and Guntram B. Wolff, 'A Compromise Estimate of German Net National Product, 1815-1913, and Its Implications for Growth and Business Cycles, *Journal of Economic History*, 65:3 (September 2005), 613-57

Carsten Burhop, 'Did Banks Cause the German Industrialization?', *Explorations in Economic History*, 43:1 (January 2006), 39-63.