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Foreign Trade Patterns, Technical Change, Cost and Productivity in the West European Iron Industries, 1820–1870*

I

My major research topic has been the development of the primary iron industry in Belgium, France and Germany from the 1820's to the 1860's. Let me briefly define which part of the sector I am talking about: It is the primary iron industry with its two stages of production. First, there is pig iron, which is smelted from the iron ore in a blast furnace. Second, there is bar iron or wrought iron. This is refined from pig iron by using either charcoal or hard-coal.

During the four decades from the 1820's onwards, the iron industries of Belgium, France and Germany experienced the same fundamental change Britain had undergone in the 18th century, namely the substitution of mineral fuel for charcoal, that is, the process of puddling, rolling and coke smelting diffused. But neither in Britain nor on the Continent did this transition, however radical, spread fast or straightforward. Rather both traditional methods of iron production alone and conbinations of the old and new technology remained economically viable for quite a long time,[1] whereas the new techniques of smelting and refining iron hat to be improved considerably and to be adapted to the particular environments of the Continental countries before they gained clear-cut cost advantages over modified traditional techniques. Thus, it is misleading to confer distinct economic superiority on the finally most advanced technology from the beginning on, in retrospection.[2] This point has to be emphasized because of a widespread misjudgment in the literature on technical change in historical perspective ("Technikgeschichte"). That is, rashly lumping together technical advances with major improvements in economic efficiency.

David Landes might be quoted as a prominent advocate of this approach. In assessing the different technological levels between Britain and Continental Europe after the end of the Napoleonic wars he states:[3]
"In view of the enormous economic superiority of these innovations one would expect the rest to have followed automatically".

* For helpful comments I wish to thank Richard H. Tilly.

1. Cf. Table A 1 of the appendix.
2. On this very common pitfall, namely the confusion of technical advance with economic superiority, in the writing of economic history see the elaborated comment by Rosenberg, Nathan, *Perspectives on Technology,* Cambridge 1976, especially chapter 11 "Factors affecting the diffusion of technology", pp. 189–210.
3. Landes, David S., *The Unbound Prometheus,* Cambridge 1972, p. 126.

I have tried to avoid this bias of the technological historiography and to describe and analyse the processes of modernization in the primary iron industries by comparing levels of prices and costs among different countries and regions over time. In a market economy with sufficient competition, costs and prices reflect the endowment with resources and the level of productivity. On this yardstick, technological achievements only become apparent when they are economically significant. Thus, the potential economic relevance of an innovation in the long run is not identical with its cost-saving contributions at the time of its first appearance, which were usually rather modest. It is however difficult to obtain reliable data on costs and prices which are representative of an entire country. Available data on costs and prices often only refer to certain regions and enterprises. Furthermore, differences in prices due to differences in quality of the product complicate comparisons.
In this article, I want to set forth two aspects:

1. structural changes in international trade, and
2. productivity changes over time. Hence I do not intend to present direct evidence here which would refute views as expressed by Landes.[4]

II

Let me now set forth the conclusiveness of structural changes, which took place in the international trade flows and in the tariff policy accordingly, focussing on France and Germany.[5] The changing pattern of trade flows among nations and the corresponding tariff policy are useful indicators to detect the international competitive position of the specific iron industry over time.

In Britain, the transition from charcoal to coke or hard-coal as a fuel for smelting and refining iron had been achieved already in the 18th century, whereas on the Continent, charcoal techniques dominated until far into the 19th century. Around 1820, the British iron industry was not only free from any real competition on her domestic market, but it was more and more able to export much of her output abroad. From the 1820's to 1870, exports of all iron products rose dramatically from one quarter to roughly 60% of the total pig iron production.[6] For the most part of the period in question, British producers were the cheapest suppliers of iron internationally.

The French tariff policy reflects very clearly the cost and price advantage of British suppliers in the early 19th century. In 1822, France established nearly prohibitive du-

4. On this see my forthcoming manuscript on *Untersuchungen zur Modernisierung der Eisenindustrie 1820–1860 — Zur Einführung des Koksschmelzens und des Puddelverfahrens in Belgien, Frankreich und Deutschland.*
5. Belgium as the first country to catch up with British technology deserves a special attention. In this paper, however, I refer to her rather occasionally, but Belgium will be analysed more thoroughly in my current research, see footnote 4 above.
6. Hyde, Charles K., *Technological Change and the British Iron Industry, 1700–1870,* Princeton 1977, pp. 144, 172; British producers in general became increasingly dependant on exports during this time, on this see Crouzet, François, *Toward an Export Economy:* British Exports during the Industrial Revolution, in: Explorations in Economic History, 17 (1980), pp. 48–93; and Davis, Ralph, *The Industrial Revolution and British Overseas Trade,* Leicester 1979.

ties especially against British iron. This law remained unchanged in principle until the mid-1850's, and then it was replaced by the Cobden-Chevalier-treaty. Such a highly effective and long-lived customs law deserves a closer look into its genesis.[7]

In 1814, the tariff on bar iron was set up in the following way: Swedish bar iron reached French ports for 350 Francs per ton. Since French bar iron was sold there at least at 500 Francs, the duty was fixed at 150 Francs, i. e. ad valorem more than 40%. The fact, that the reference price was Swedish iron, reflects that Sweden was still considered the dominating supplier of iron on the international market. Obviously, the French were not yet aware that in the meantime Britain had become the supplier at lowest prices on the world market. In spite of this high protective duty of 1814, British bar iron was dumped in large quantities on the French market. In 1820 and 1821, nearly 80% of all bar iron imports came from Britain. 1819 is the only year before 1822 for which a French output figure can be compared to imports: The ratio between imports and production made up 0.14. These imports must have been perceptible for French producers.

So the new tariff of 1822 was solely directed against British imports. Numerous petitions of iron masters had convinced the government of the necessity to increase the duty on iron. The following calculation was made up: British bar iron was sold at 400 Francs per ton, including the already existing tariff. French bar iron could not be sold cheaper than 500 Francs per ton, so the existing tariff of 150 Francs was raised to 250 Francs. This measure was solely taken against British puddled and rolled bar iron, whereas Swedish hammered charcoal bar iron still bore the duty of 1814. British bar iron now suffered a duty of 100% ad valorem.[8] This discriminatory duty had immediate effects on British bar iron exports to France: While in 1821 still one third of all British bar iron exports had gone to France, this share dropped dramatically in the following years. Not even the 8% of 1822 could be matched in the years to come.[9]

In short, the wall of protectionism kept British bar iron imports down. And any importation of pig iron, which might have been worked up to bar iron along the coast should be blocked likewise. So the duty on British pig iron was raised adequately, namely from 20 to 90 Francs per ton.[10] Thereafter only foundries imported British pig iron.[11] These tariffs, both on bar iron and on pig iron, were not lowered markedly

7. Detailed documentation based on records in the "Archives Nationales" is to be found in Fremdling, Rainer, *Britische Exporte und französische Schutzzollpolitik, Zur Entstehung und Auswirkung der Eisenzölle von 1822,* in: Scripta Mercaturae, 14 (1980), pp. 55–70.
8. According to the calculation of a government official the ad valorem duty, including the "décime" (tith), was raised from 70 to more than 120 percent, Archives Nationales F 12 2529, Report of the 18.8.1821; see also Amé, M., *Étude sur les tarifs de douanes et sur les traités de commerce,* Paris 1876, p. 145.
9. See Tables A 1 and A 2 of the appendix.
10. Before the new duty was introduced bar iron produced from imported pig iron had to bear a duty of 30 Francs. An input-output-coefficient of 1.5 was assumed. The additional pig iron duty of 70 Francs multiplied by 1.5 was about the 100 Francs increase on the bar iron duty. On details of this calculation see the report mentioned in footnote 8.
11. Continental producers could hardly attain the quality of British foundry pig iron for certain purposes. This was e. g. clearly expressed in the minutes of the *Enquête sur les fers,* Paris 1829, pp. 103–110, 151.

before the 1850's, and finally by the Cobden-Chevalier-treaty in 1861. But even then, they still made up between 30 and 40% ad valorem on bar iron, and between 20 and 30% on pig iron.[12]

Table 1: French Iron Production, Imports and Exports, 1825–1870, thousands of metric tons and ratios, annual averages

Years	Pig Iron Production (P)	Imports (M)	Exports (X)	$\frac{X - M}{X + M}$	$\frac{M - X}{P}$
1824/30	220.9	8.8	0.9	-0.81	0.04
1831/40	293.6	13.4	0.4	-0.94	0.04
1841/50	447.2	49.9	0.4	-0.98	0.11
1851/60	780.0	70.7 (+ 19.4)[a]	0.8	-0.98 (-0.98)[a]	0.09 (0.11)[a]
1861/70	1,191.5	79.1 (+ 73.1)[a]	0.7	-0.98 (-0.99)[a]	0.07 (0.13)[a]

Years	Bar Iron[1] Production (P)	Imports (M)	Exports (X)	$\frac{X - M}{X + M}$	$\frac{M - X}{P}$
1825/30	148.6	6.9	0.5	-0.86	0.04
1831/40	195.2	5.6	0.5	-0.84	0.03
1841/50	301.7	6.7	0.8	-0.80	0.02
1851/60	480.0	18.1 (+ 1.9)[a]	2.1 (+5.1)[a]	-0.79 (-0.47)[a]	0.03 (0.03)[a]
1861/70	767.0	12.2 (+16.4)[a]	2.5 (+28.9)[a]	-0.66 (0.05)[a]	0.01 (-0.004)[a]

1 including rails

a The "commerce spécial" is a category in which imports allowed under the system of "admission temporaire" are not included. It can be corrected by means of the following formula: S = commerce spécial; G = commerce général $(M_G - M_S) - (X_G - X_S)$.

Sources: See appendix.

12. Cf. Boiteau, Paul, *Les traités de commerce, Texte de tous les traités en vigueur notamment des traités conclus avec l'Angleterre, la Belgique, la Prusse (Zollverein) et l'Italie*, Paris 1863, p. 10; duties on bar iron and rails were reduced to 70 and 60 Francs per metric ton, and on pig iron to 25 and 20 Francs, in 1860 and 1864 respectively.

Table 1 demonstrates which impact the French tariff policy had on imports and exports. The ratios in the last column show the relation of net imports to production. The export-import-ratios were calculated after a suggestion of Bela Balassa.[13] They reflect the "revealed comparative advantage", and indicate differences in costs and other factors determining international trade, e.g. tariffs and transportation costs. The value of these ratios could fluctuate between plus and minus 1. A high positive value reveals a comparative advantage, the opposite is true of negative values.

These ratios clearly show that France had considerable comparative disadvantages concerning pig iron over the whole time-span. The high import duties, however, kept the level of imports in relation to production during the 1820's and 1830's extremely low. But the refining branch south of the Belgian-French border had been a consumer of Belgian pig iron for a long time, and this Belgian pig iron could be imported at less than half of the rate for British iron.[14] So northern France continued buying Belgian pig iron, and bought even more since the 1840's. This coke pig iron was worked up to bar iron in modern puddling and rolling mills.[15] The imports amounted to around 10% of the indigenous production, and they remained high. But from 1855 on, Belgian pig iron had to bear the same duty as the British product. From that time on, British exports surpassed those of Belgium by far, a striking evidence that British suppliers were still producers at the lowest costs internationally.

Throughout the period the level of bar iron imports to France remained very low compared to that of the French production. The export-import ratios reveal a clear comparative disadvantage well into the 1850's. However, the system of "admission temporaire" provided an incentive to exports for works in the south and centre of France. This virtual premium on exports helped improve the French international trade position considerably.[16] In the 1860's, France even became net-exporter of rails and bar iron.

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13. Balassa, Bela, *Trade Liberalisation and "Revealed" Comparative Advantage,* in: Manchester School of Economic and Social Studies, (1965), pp. 102f. and pass.; see also Dumke, Rolf H., *The Political Economy of German Unification: Tariffs, Trade and Politics of the Zollverein Era,* Diss. University of Wisconsin, Madison 1976, pp. 151, 186.
14. On Belgian pig iron a duty of between 40 and 60 Francs per metric ton was levied, Archives Nationales F 12 2513, Question des fers, Report of 1841.
15. There are reports that in the early 1840's Belgian rolling masters founded rolling mills south ot the Belgian border in France to work up Belgian pig iron to bar iron and rails, Stainier, Emile, *Histoire commerciale de la métallurgie dans le district de Charleroi de 1829 à 1867,* Charleroi 1873[2], pp. 45f.
16. The system of "admission temporaire" worked in the following way: E.g. exporters of rails to Spain got a certificate to import free of duty an equivalent of pig iron. In general the exporter of rails—let us say an iron master in the south of France—did not use this certificate ("aquits-à-caution") to import pig iron himself but he sold it to an importer of pig iron in the north of France. On this see Lexis, W., *Die französischen Ausfuhrprämien im Zusammenhang mit der Tarifgeschichte und Handelsentwicklung Frankreichs seit der Restauration,* Bonn 1870, pp. 400ff.; Ministère de l'agriculture, du commerce et des travaux publics, *Enquête sur l'application du décret du 15 février 1862, relatif à l'importation en franchise temporaire des métaux,* Paris 1867, pp. 25ff.; Levasseur, E., *Histoire du commerce de la France,* vol. 2, Paris 1912, pp. 304ff.

In the next section, I want to discuss the tariff policy of Prussia/Germany. The Prussian tariff of 1818 was later adopted by the Zollverein.[17] It exercised a great influence on determining the route over which the new iron techniques penetrated into the western parts of Germany, namely the Rhineland and Westphalia.[18]

The tariff on bar iron was fixed at 60 Marks per ton.[19] From 1825 to 1830, the first years for which Prussian data on foreign trade are available, this tariff rate meant an ad valorem duty of 40 to 21%. The French tariff on British iron at the same price was four times as high.[20] At first sight it is astonishing that there was no duty levied on pig iron imports. It was treated as a raw material, which could enter the country free of duty according to the conception of the 1818 Prussian tariff system. At the time when the Prussian tariff was established, British coke pig iron did not play any role on the German market. And the free importation of pig iron was granted because Prussian refineries should work up charcoal pig iron from other German states.[21] Thus, the Prussian tariff policy was comparatively liberal. And it could afford to be so, as during the 1820's and the early 1830's, Germany's indigenous producers were not seriously challenged by British exports. Only in slump years, when British prices were extremely low, British bar iron and some pig iron penetrated into traditionally iron-producing regions of Germany. But by and large the domestic charcoal iron industry produced at costs low enough to meet British competitors on its internal markets. The low level of British iron exports to Germany at this time was partly due to the structure of demand in Germany. Traditional consumers of iron still preferred traditionally produced charcoal iron.[22]

The special set-up of the tariff, however, brought about a rather peculiar modernization process of the German iron industry. This became palpable when the railway construction in Germany increased the demand for cheap mass-produced iron, which happened since the mid-1830's. Until the early 1840's, the new railway demand was mainly satisfied by British producers. But in the second stage the German primary iron industry modernized quickly: German iron masters were soon capable of producing puddled and rolled iron. They used imported coke pig iron from Britain, and since 1844 increasingly from Belgium, too, and worked it up to bar iron or rails in their modern iron works. Usually these new rolling mills did not have any blast furnace to smelt their own pig iron. So they remained dependent on pig iron imports.

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17. See Ohnishi, Takeo, *Zolltarifpolitik Preußens bis zur Gründung des Deutschen Zollvereins*, Diss. Göttingen 1973, p. 1; Dumke, *Political Economy*, pp. 247ff.; Treue, Wilhelm, *Wirtschaftszustände und Wirtschaftspolitik in Preußen 1815–1825*, Stuttgart 1937, pp. 114–159.
18. On the iron duties see Sering, Max, *Geschichte der preussisch-deutschen Eisenzölle von 1818 bis zur Gegenwart*, Leipzig 1882.
19. Sering, *Eisenzölle*, p. 20 and Anhang 2.
20. Based on bar iron prices in Liverpool and pig iron prices in Glasgow, the freight rate was assumed at 16 Mark per metric ton to French ports and at 21 Mark to the Prussian boarder on the Rhine. On the prices see Griffiths, Samual, *Guide to the Iron Trade of Great Britain*, new ed., n.p. 1967, pp. 288f.; Meade, Richard, *The Coal and Iron Industries of the United Kingdom*, London 1882, p. 741.
21. Oechelhäuser, Wilhelm, *Der Zollverein, Seine Verfassung, sein handelspolitisches System und die Entwicklung der Tarifsätze seit 1818*, Frankfurt a.M. 1851, pp. 58f.
22. At that time the finishing branches of the iron industry were still dominated by small, rural works.

That is why the import substitution process on the level of bar iron and rails was accompanied by a dramatic increase of imported pig iron since the early 1840's.[23]

This development in the refining branches challenged the producers of charcoal pig iron seriously. Just a bit of the incremental demand for railway construction was directed to them, and even worse, their traditional customers of bar iron were learning how to use puddled bars. And these had either been imported or more and more of them had been produced in Germany from imported coke pig iron. In the early 1840's, this development coincided with very low prices on the world market.

To protect the smelting branch of the iron industry the Zollverein introduced a tariff on pig iron, which amounted to 20 Marks per ton. As a compensation for the increased input prices iron masters with their modern rolling mills now had to bear, the duty on bar iron was raised accordingly, namely from 60 Marks to 90 Marks per ton.[24]

In 1844, this specific tariff meant 70% ad valorem on bar iron, and nearly 30% on pig iron, based on British prices before the German border on the Rhine. The comparable French duties were two or three times as high.[25]

The 1844 tariff granted Belgium special treatment. Belgian iron exporters had to bear only half of the pig iron duty and half of the incremental duty on bar iron. After 1844, therefore, Belgian coke pig iron succeeded at the expense of British iron, and now rolling mills on the right bank of the Rhine also used Belgian instead of Scottish pig iron. For some years, Belgium's exports to Germany even surpassed those from Britain. So the Belgian success on exports markets proved Britain's world domination there to be vulnerable.[26]

After 1854, Belgium lost her privilege, and even then she still exported large quantities into the Zollverein. The fact that Belgian producers maintained a strong position on the French and German market even after they had lost their preferential treatment indicates that Belgium's productive capacity had grown considerably.[27] At least since the mid-1850's, Belgium produced iron at costs not much higher than in Britain. But for all that, Belgian costs actually *were* a bit higher, which may be con-

23. This argument has been developed more thoroughly in Fremdling, Rainer, *Railroads and German Economic Growth: A Leading Sector Analysis with a Comparison to the United States and Great Britain,* in: Journal of Economic History, 37 (1977), pp. 583–604, and Fremdling, Rainer, *Britische Exporte und die Modernisierung der deutschen Eisenindustrie während der Frühindustrialisierung,* in: Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte, 68 (1981), pp. 305–324.
24. An input-output-coefficient of 1.5 was assumed. The pig iron duty of 20 Mark per metric ton multiplied by 1.5 matched the increase of the bar iron duty. See Sering, *Eisenzölle,* pp. 65 ff., 74.
25. See footnote 20.
26. Sydow, Helmut, *Die Handelsbeziehungen zwischen Belgien und dem Zollverein 1830–1885,* vol. 1, Cologne 1979, pp. 79 ff.; Oechelhäuser, Wilhelm, *Denkschrift über den Vertrag des Zollvereins mit Belgien und die Lage der vereinsländischen Eisenindustrie,* Frankfurt a. M. 1851, pp. 6 f. and pass.
27. The precise figures of Belgian exports broken down to receiving countries are to be found in: Le Ministère de l'Intérieur, *Tableau général du commerce de la Belgique avec les pays étrangers, pendant l'anneé* 1,831 ff.

cluded from larger British import shares both in Germany and in France during the late 1850's and 1860's.

Table 2: German[1] Iron Production, Imports and Exports, 1825–1870, thousands of metric tons and ratios, annual averages

Years	Pig Iron Production (P)	Imports (M)	Exports (X)	$\frac{X - M}{X + M}$	$\frac{M - X}{P}$
1825/30	56.8	3.8	3.5	-0.03	0.004
1831/33	71.0	5.0	1.9	-0.45	0.04
1834/40	149.0	14.2	1.8	-0.77	0.08
1841/50	196.4	75.2	1.8	-0.95	0.37
1851/60	411.5	150.5	5.3	-0.93	0.35
1861/70	1,022.5	154.0	41.5	-0.58	0.11

Years	Bar Iron[2] Production (P)	Imports (M)	Exports (X)	$\frac{X - M}{X + M}$	$\frac{M - X}{P}$
1825/30	34.1	3.7	1.8	-0.35	0.06
1831/33	40.7	5.3	3.4	-0.22	0.05
1834/40	66.0	13.1	2.3	-0.71	0.16
1841/50	128.4	35.2	2.2	-0.88	0.26
1851/60	257.6	20.1	6.1	-0.53	0.05
1861/70	528.5	13.9	28.8	0.35	-0.03

1 until 1833 Prussia; from then on the Zollverein

2 including rails

Sources: See appendix.

Table 2 reflects the shifts in the foreign trade position of Prussia or the Zollverein. In the 1820's, the export-import-ratios for pig iron reveal no clear-cut comparative disadvantage yet, but from the 1830's until the late 1850's, the ratios become unfavourable. In the 1860's, Germany could improve her trade position by exporting large quantities of bar iron, though the level of imports still remained quite high. The extraordinary importance of imports compared to the domestic production is shown in

the last column of Table 2. These high ratios indicate that the development of the refining branch, the puddling and rolling mills, could not have been achieved without Britain and Belgium delivering the necessary inputs. In this way the refining branch with its bar iron and rail production modernized earlier and faster than the smelting branch. The ratios for bar iron indicate that the comparative disadvantage became more pronounced until the 1840's. The high net-imports in the late 1830's and in the 1840's were mainly caused by the extraordinary demand for railway construction. But from then on, the foreign trade position of Germany improved considerably. The process of import substitution was completed when Germany became a net-exporter of rails and bar iron in the 1860's.

Looking back at the development of the German and French primary iron industry one may briefly note some similarities or differences: In Prussia/Germany the modernization started later, but was carried through more rapidly than in France. By the late 1850's, both countries had reached a similar technical level. This level can be defined as the degree to which mineral fuel was used for smelting and refining iron.[28] In both countries, the second stage of primary iron production modernized sooner and much faster than the first. Each of them became a net-exporter of bar iron and rails in the 1860's. In both countries, pig iron imports still played a major role in the 1860's, thus providing the refinery branches and foundries with cheap inputs at sufficient quantities. A principal difference lay in the tariff policy and the resultant role of imports over the period: In France, high tariffs allowed a delayed, long-drawn and rather smooth transition making more use of internal resources. In Germany, lower tariffs led to a fast and rather abrupt change drawing considerably on external intermediate products.[29] It seems that by the 1860's both countries had acquired productivity gains high enough for them to lower their tariffs on primary iron products. At this point, they simply could afford a liberalization, e.g. that of the Cobden-Chevalier-treaty.[30]

The shifting international trade positions of west European countries are mirrored in the British foreign trade statistics. The bulk of the data is not presented here, but is confined to the shifts in British exports of bar iron and pig iron. Table 3 presents ratios of bar iron to pig iron, and they clearly indicate that right from the 1820's onwards, Britain began losing her absolute advantage in the refining stage of the primary iron industry much faster than in the smelting stage. In exporting huge amounts of pig iron she even supported the catching-up process in other countries.

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28. During the most part of the period in question both countries ranged far behind Belgium. See Table A 1 of the appendix.
29. France exploited much longer the wealth of the charcoal iron producing regions, the wood.
30. Mark per metric ton:
    Pig iron: D 1865 = 15 M, 1868 = 10 M, 1870 = 5 M;
    F 1855 = 32 M, 1861 = 20 M, 1864 = 18 M;
    Bar iron: D 1865 = 50 M, 1870 = 35 M;
    F 1855 = 80 M, 1861 = 54 M; 1864 = 48 M.
    Sering, *Eisenzölle*, Anhang 2;
    Archives Nationales F 12 2513, Etudes sur les résultats ...;
    Boiteau, *Traités*, p. 10.

Table 3: British Iron Exports, 1821–1870, thousands of metric tons and ratios, annual average

Years	Pig Iron (1) total	to Germany + Holland	Bar Iron[1] (2) total	to Germany + Holland	Ratio (2) / (1)[2] total	to Germany + Holland
1821/25	4.5	o.2	3o.5	2.2	8.5	13.8
1826/3o	8.5	1.2	49.3	5.8	7.3	6.o
1831/35	21.6	2.1	76.4	9.1	4.4	5.4
1836/4o	44.5	1o.3	112.8	14.9	3.2	1.8
1841/45	1o3.7	45.3	183.o	52.5	2.2	1.4
1846/5o	165.o	43.7	3o4.3	36.3	2.3	1.o
1851/55	276.4	72.4	575.7	41.o	2.6	o.7
1856/6o	366.1	136.3	742.2	64.o	2.5	o.6
1861/65	47o.o	157.2	627.5	48.8	1.7	o.4
1866/7o	626.5	187.8	874.6	46.8	1.7	o.3

1 including rails

2 for bar iron a multiplier of 1.25 was used to obtain pig iron equivalents

Sources: See appendix.

III

In the last section of this paper, I want to present some comparable data on costs and prices mainly for 1860 or 1861. Further, I intend to measure productivity gains over time by using price ratios of the major input and the output.

Table 4 gives data on variable costs. The cost structure within the iron industry is relevant for the approach in which productivity levels are measured across countries or over time periods. As already Donald N. McCloskey[31] has written in his study on the British iron and steel industry, this sector is characterized by "material-intensity and capital-lightness", notwithstanding common belief. Productivity measurement in this industry has to take into account the peculiar structure of inputs.

"'Productivity' is customarily defined as output per man or output per composite unit of men and machines, setting aside inputs of material from other industries. Although this definition is appropriate for measuring productivity in the nation as a whole, it is not for measuring it in one industry alone, whatever the end in view. It is inappropriate if the measure is meant to reflect the increased national income generated by technological change or improved efficiency in the industry, for these events

31. McCloskey, Donald, N., *Economic Maturity and Entrepreneurial Decline, British Iron and Steel, 1870–1913*, Cambridge Mass. 1973, p. 74.

release for alternative employment the labor and capital embodied in materials used by the industry as well as the labor and capital used directly. And it is also inappropriate if the measure is meant to reflect the responsiveness of entrepreneurs to market pressures to minimize costs, for these pressures induce entrepreneurs to save materials as well as labor and capital directly employed in the industry. Measures of productivity change for single industries should include material inputs."

The shares which costs of fuel and iron ore took, clearly reveal that material inputs made up most of the costs of pig iron production by far. But there are striking variations among different countries, regions or enterprises in the shares of costs of fuel or

Table 4: Pig Iron Costs, percent and Mark (M) per metric ton

Year		Country	(1) Fuel in % of (3)	(2) Iron Ore in % of (3)	(3) Variable Costs	
(1)	1841	Blair Scotland (GB)	32.2	46.7	29.9 M	
(2)	1843	Champagne (F)	68.2	14.2	113.o M	charcoal pig iron (includes "frais généraux")
(3)	1847	Dowlais South-Wales (GB)	24.3	61.4	56.2 M	
(4)	1846/ 1847	S.A.Marcinelle et Couillet (GB)	29.3	42.9	79.o M	
(5)	1847	S.A.Espérance Seraing (B)	32.1	3o.2	7o.2 M	
(6)	1848	S.A. Cockerill	42.8	44.1	75.9 M	pig for castings
		Seraing (B)	43.3	41.6	48.3 M	forge pig
(7)	186o	S.A. Cockerill Seraing (B)	3o.3-31.4	53-54	56-54 M	
(8)	186o	Alais	54.1	33.9	54.6 M	pig for rails
		Dépt. Gard (F)	54.2-57.2	38.o-37.7	83.7-89.o M	pig for "fer marchand"
(9)	1861/ 1862	Hochdahl Düsseldorf (D)	27.7	57.8	71.6 M	
(1o)	1862	Siegerland Westphalia(D)	59.7	36.9	67.o M	charcoal pig iron
(11)	1867	France Average (F)	62.9	16.4	52.o-56.o M	
(12)	1867	Cleveland (GB)	46.2	32.9	48.8 M	

1 Franc = o.8 Mark = o.8 Shilling; GB = Great Britain, F = France, B = Belgium, D = Germany.

Sources: See appendix.

ore. Besides my British data in Table 4, which vary considerably, one can draw on Robert Allen's data.[32] In the 1850's, fuel costs made up 44% of riable costs in Cleveland, 22% in Scotland, and 18% in South Wales, whereas the fuel shares of Cockerill and Hochdahl amounted to around 30%, and the extremely high French values were around 60%. The last figure was matched or even surpassed by traditional charcoal blast furnaces.

All these data, and I could add more on different regions and periods, support the statement, that one cannot assume a world, which followed a Cobb-Douglas-production-function for the period in question. The data do not fit into a system with constant factor shares and the same corresponding elasticities of production across countries and over time. Hence, this theoretically easy way to combine output-input-ratios to indices of total factor productivity cannot be pursued. This procedure would have been complicated on empirical grounds anyway: During the time-span from the 1820's to the 1860's, it is extremely difficult to get reliable and representative time series on physical input-output-quantities and ratios as e.g. the coke rate.[33] The information is rather sparse and fragile, and could easily lead to errors in measurement.

I suppose, a safer way to measure productivity gains over time might be to use price series of output and inputs. Within the framework of neoclassical theory, as it was put forward by Donald N. McCloskey and others, this approach might be equivalent to the use of physical input-output-quantities.[34] Even in periods, when sufficient competition is not always granted, prices could be used to estimate productivity over time.

"One way to apply the reasoning is to compare the prices of products at different dates. The price of a finished product, heavy steel rails, say, rose and fell because of changes in the prices of inputs, changes in productivity, and changes in the degree of monopoly power. The price of the most important input, pig iron, is readily available. The observed ratio of the rail price to the pig iron price will reflect productivity and the degree of monopoly power. ... The trend in the ratios is an estimate of the trend of productivity in railmaking ..."[35]

Following this reasoning I estimated the growth rates in Table 5. At first I refer to the pig iron production. As it is commonly assumed that ore requirements are not subject to productivity improvements,[36] I only used the other major input, the fuel, to detect productivity changes over time.[37] Due to the lack of data I had to calculate the

32. Allen, Robert, C., International Competition in Iron and Steel, 1850–1913, in: Journal of Economic History, 39 (1979), p. 921.
33. I.e. the amount of coke needed to produce one ton of pig iron. For Britain Riden has recently emphasized that it was extremely difficult if not impossible at all to get consistent time series on physical consumption of raw materials, Riden, Philip J., *The Iron Industry*, in: Church, Roy (ed.), The Dynamics of Victorian Business, London 1980, pp. 71 ff.
34. McCloskey, *Economic Maturity*, pp. 29, 86; Temin, Peter, *Iron and Steel in Nineteenth-Century America*, Cambridge Mass. 1964, p. 187.
35. McCloskey, *Economic Maturity*, pp. 24 f.
36. McCloskey, *Economic Maturity*, pp. 77 f.; Allen, Robert C., *The Peculiar Productivity History of American Blast Furnaces, 1840–1913*, in: Journal of Economic History, 37 (1977), p. 608.
37. E.g. Labour costs usually were below 10 percent, Isard, Walter, *Some Locational Factors in the Iron and Steel Industry since the Early Nineteenth Century*, in: Journal of Political Economy, 56 (1948), p. 203, footnote 4.

Table 5a: Ratios of Coke Pig Iron Prices to Fuel Prices, annual growth rates

Country	Period				
	1833-187o	1834-187o	1839-187o	1845-187o	185o-187o
GB	- 2.77^{++}			- 1.64^{++}	- 1.13^{++}
B				- 3.28^{++}	- 3.68^{++}
F Dépt. Nord			- 3.44^{++}	- 3.86^{++}	- 3.4o^{++}
F Dépt. Loire		- 1.1^{++}	- 1.96^{++}	- 1.92^{++}	- 1.42^{++}
D U. Silesia					- 2.63^{++}
D Ruhr					- 1.58[a]

Table 5 b Ratios of Bar Iron Prices to Pig Iron Prices, annual growth rates

GB	+			-	-
B				- (Rails -o.6^{+})	- (Rails-)
F Dépt. Nord			+ o.45^{+}	+ (Rails +)[b]	+ (Rails + o.46^{+})
F Dépt. Loire		+	+	+ (Rails -1.23^{++})[b]	- (Rails -1.54^{++})
D Ruhr					-

a nearly significant (5 %), b 1847 - 187o

The growth rates are derived from estimated values of a linear trend function; in cases where the linear trend function was not significant (++ 1 %; + 5 %) only the sign of the slope is given.

Sources: See appendix.

growth rates for different comparable time periods. With the exception of the Département Loire and the Ruhr area the ratios of pig iron to fuel prices show the expected picture: Continental countries or regions achieved considerably higher productivity gains between 1845 (or 1850) and 1870 than Britain.

Thus, the shifting foreign trade position between Britain and Continental countries, with these countries lowering their import duties mainly in the 1860's, corresponds very well with the fact described here, that Continental iron producers were able to reduce the cost differences in producing pig iron. Britain remained producer at lowest costs, however.

Obviously, Continental iron masters had been forced to economize on fuel rather early, whereas British producers had been used to drawing on cheap readily available fuel. This is explicitly stated in the Report on Coal:[38]

"It is certain that until recently there has been both an enormous waste of fuel in the production of heat, and a considerable waste of heat when produced, in all furnaces in which it has been necessary to obtain an elevated temperature." In the minutes to this report, Isaac Lowthian Bell, an authority on the iron industry, said:[39] "If you go back 40 years ... the small coal ... was so complete a drug in the market that immense quantities were wasted; ... the consequence was that an immense quantitiy of coal was left under ground, and the portion which was separated by the screens was allowed to accumulate at the pit head, and there it took fire and was lost."

In this case it seems that Continental iron masters enjoyed the advantage of backwardness. At a time when Britain could still draw on her immense supplies of cheap fuel Continental producers were much more forced to apply fuel-saving devices. Thus, the Continent rapidly adopted the hot blast, which had been developed in Scotland, but which was applied in other British iron producing regions rather hesitantly.[40] And there were innovations on the Continent to use the waste gases of the blast furnace to heat the hot blast and subsequently puddling furnaces as well. Not by accident was the utilization of waste gases developed within the field of traditional charcoal iron industry, which was much more under pressure to economize on fuel.[41]

I have mentioned above that the Ruhr area and the Département Loire had exceptionally low growth rates concerning the ratios for pig iron. In order to explain why the Département Loire in the south of France merely achieved significantly lower productivity gains than the Département Nord, specific enterprises in both regions

38. *Report of the Commissioners Appointed to Inquire into Serveral Matters Relating to Coal in the United Kingdom,* in: Parliamentary Papers, XVIII (1871), p. 96.
39. *Report from the Select Committee on Coal; with the Proceedings of the Committee, Minutes of Evidence,* in: Parliamentary Papers, X (1873), p. 237.
40. The introduction of the hot blast led to drastic reductions in fuel consumption. Thus its cost-saving function was highest where fuel costs were highest. Within Britain this was true of Scotland compared to South-Wales and internationally it was true of Continental countries compared to Britain. Hyde, *Technological Change,* pp. 146–159; Bell, Isaac Lowthian, *The Iron Trade of the United Kingdom Compared with of the other chief Iron-Making Nations,* London 1886, p. 100.
41. E.g. in Württemberg (southern Germany), where since 1830 Faber du Faur had developed several devices to use waste gases. Beck, Ludwig, *Die Geschichte des Eisens in technischer und kulturgeschichtlicher Beziehung, 1801–1860,* Braunschweig 1899, pp. 412ff., 434f.

ought to be scrutinized and compared. But let me simply try an informed guess here: It is conspicuous that the Département Loire considerably increased its productivity of rail-making, as measured in Table 5. My explanation for this seeming inconsistency is that pig iron prices here do not reflect the considerable improvements in the quality of the pig iron produced. I assume that over time in this region the amount of pig iron necessary to produce a certain quantity of rails had dropped considerably. I know this for sure concerning a comparable region, the Département Aveyron. There the quantity of pig iron needed to produce rails dropped dramatically, whereas the prices of pig iron fell only slightly.[42] This argument gives a hint of the limitations of measuring productivity changes over time by using price data. Certainly, this approach is biased when quality changes are not taken into account.

The case of the Ruhr area requires a different explanation. The most striking evidence here seems to be the lateness of introducing coke blast furnaces into this region. The first one was successfully put into blast only in 1849.[43] Given the fact that the Ruhr area had drawn considerably on cheap foreign coke pig iron for quite a time it seems plausible that entrepeneurs could afford to wait for the blast furnace to have developed a high practice standard. And only then did the Ruhr iron masters enter the pig iron market and erect a lot of *modern* blast furnaces of their own. Hence, the works of Hochdahl, which were considered to be representative of the price and qualitiy of forge pig iron, could experience only slight decreases in costs during the 1860's: Having taken up the production of pig iron in 1861 at a highly modern standard they could hardly develop further in the 1860's.[44]

Let me now turn to the refining sector. The overwhelming cost factor to produce bar iron or rails is pig iron, which amounted to usually more than 50%.[45] If we exclude rail prices the trend functions on the ratios of bar iron to pig iron prices are not significant. By this measure the refining branch does not show any traceable productivity gains, neither in Britain nor on the Continent.[46] But the fact that bar iron prices moved parallel to pig iron prices intimates that there must have been certain productivity gains in the refining branch, too.

42. E.g. in the Département Aveyron the extraordinary amount of 1.75 tons of pig iron was needed to produce one ton of bar iron in 1834. The average price for pig iron was 70 Mark per metric ton between 1834 and 1840, and 72 Mark between 1861 and 1870, compiled from the various issues of the French mineral statistics: Source, see the note on France of Table 5. As suggested by François Crouzet in the discussion of this paper the Département Loire had already developed the best practice standard very early, therefore the possibility of productivity gains in the years to come could not exceed those of the pacemaker i.e. Britian.
43. Lange-Kothe, Irmgard, *Die ersten Kokshochöfen in Deutschland, besonders im Rheinland und in Westfalen*, in: Stahl und Eisen, 85 (1965), pp. 1053–1061.
44. On the costs of the Hochdahl iron works see *Reichs-Enquete für die Eisenindustrie*, n.p. or d., p. 254; as another example, where the coke rate did not show any decrease from 1854 to 1870, the "Eisenhütte Berge-Borbeck" is presented by Fischer, Wolfram, *Herz des Reviers*, Essen 1965, pp. 100f.
45. Conseil supérieur de l'agriculture, du commerce et de l'industrie, *Enquête, Traité de commerce avec l'Angleterre, Industrie métallurgique*, vol. 1, Paris 1860, p. 643f.; Glamorgan Record Office Cardiff, Dowlais Works, D/DG Sect. C Box 4.
46. Concerning Britain see Hyde, Technological Change, pp. 166, 176.

As the technology of puddling and rolling was rather easy to adopt it was applied everywhere in the relevant Continental countries quite successfully already in the 1820's. Since these techniques could be used to work up charcoal pig iron as well (it was often mixed with coke pig iron) the modern mineral fuel techniques spread much faster through in this stage than the coke blast furnace.[47] Hence, it seems plau-

Table 6: Pig Iron Prices at the Works, Mark (M) per metric ton, 1860 or 1861

D	(1)	Düren (left bank of the Rhine near Aachen)	75 M 85.3 M (charcoal pig)
	(2)	Dortmund (eastern Ruhr)	81.7 M
	(3)	Oberhausen (western Ruhr)	76.3 M
	(4)	Düsseldorf (Hochdahl)	85.1 M
	(5)	Georgs-Marien-Hütte (south of Osnabrück)	84.4 M
	(6)	Upper-Silesia	66-72 M
		"	9o M (charcoal pig)
B	(7)	Seraing (S.A. Cockerill)	6o-64 M
	(8)	National Average	63.6-65.1 M
		"	1o2.5-1o5.9 M (charcoal pig)
F	(9)	Dépt. Haute Marne	99 M (charcoal pig)
	(1o)	Dépt. Nord	96-1o1 M
	(11)	Dépt. Loire	81-84 M
	(12)	Dépt. Aveyron	8o M
	(13)	Dépt. Saône-et-Loire	76-77 M
	(14)	Dépt. Moselle	74-75 M
		"	124-128 M (charcoal pig)
GB	(15)	Glasgow	48.5-52.9 M
	(16)	South Wales	69.o-83.1 M

Import Duties: D 2o M p t
B 16 M p t
F 32 M p t (2o M from 1861 onwards)

Costs of transportation to Continental ports, around: 16 M p t

Sources: See appendix.

47. France is a good example, for the 1820's see *Enquête sur les fers*, pass.

sible that already during the mid-1840's the costs for working up pig iron were not significantly different from those in Britain. And still existing productivity differences, e. i. of the puddlers, which are reported by contemporary observers, were compensated for by adequate reductions in wages on the Continent.

To conclude the tentative reasoning on the data presented in Table 5 a major shortcoming should be mentioned: The whole charcoal iron industry was missed out, although this branch was still very important in the mid-century. For example in the years of 1848 to 1850, in France only 41% of the pig iron were smelted with coke as a fuel and in Prussia only 23%.[48] Therefore, a thorough analysis of the primary iron sector from the 1820 to the 1860's has to pay due regard to this traditonal branch.

But notwithstanding all developments on the Continent, it is worth repeating that even around 1860 Britain had in general maintained her position as lowest cost producer, both of pig iron and of bar iron. Comparing prices (as shown in Table 6) it is, however, pretty clear that the still existing import duties and transportation costs allowed indigenous producers in France, Belgium and Germany to satisfy the demand in most parts of their *home* countries at prices equal to the British prices or even lower.

Appendix

Sources on Table 1:

On the production figures see the notes on Table A 1. On the foreign trade figures see Administration des Douanes, *Tableau général du commerce de la France avec ses colonies et les puissances étrangères, pendant l'année...*, Paris..., Years 1825–1870.

Sources on Table 2:

On the production figures see Marchand, *Säkularstatistik,* pp. 88, 115, 129. On the foreign trade figures see Ferber, C. W., *Beiträge zur Kenntniß des gewerblichen und commerciellen Zustandes der preußischen Monarchie,* Berlin 1829, pp. 29ff.; Ferber, C. W., *Neue Beiträge...*, 1832, p. 23; Dieterici, C. F. W., *Statistische Uebersicht der wichtigsten Gegenstände des Verkehrs und Verbrauchs im preußischen Staate und im deutschen Zollverbande, in dem Zeitraume von 1831 bis 1836,* Berlin 1838, p. 95; Sering, Max, *Geschichte der preussisch-deutschen Eisenzölle von 1818 bis zur Gegenwart,* Leipzig 1882, pp. 290f.

Sources on Table 3:

The iron export data are to be found in the respective yearly volume of the Parliamentary Papers. Cf. 1825 XXI; 1829 XVII; 1830–31 X; 1831–32 XXXIV; 1833 XXXIII; 1835 XLVIII; 1839 XLVI; 1840 XLIV; 1842 XXXIX; 1843 LII; 1844 XLV; 1845 XLVI; 1846 XLIV; 1847–48 LVIII; 1849 L; 1851 LIII; 1854 LXVI; 1854–55 LI; 1856 LVI; 1857 XXXV; 1857–58 LIV; 1859 XXVIII; 1860 LXIV; 1861 LX; 1862

48. Cf. Table A 1 of the appendix.

LVI; 1863 LXV; 1864 LVII; 1865 LII; 1866 LXVIII; 1867 LXVI; 1867–68 LXVII; 1868–69 LVIII; 1870 LXIII; 1871 LXIII P. II. Exports to Ireland, the Channel Islands (Guernsey, Jersey, Alderney) and the Isle of Man were subtracted from the total.

Sources on Table 4:

(1) Hyde, Charles K., *Technological Change and the British Iron Industry, 1700–1870,* Princeton 1977, p. 153;
(2) Archives Nationales Paris, F 12 2223, Fonderies de Dammarie to Le Directeur Général des Forêts, 16.–11.–1843;
(3) Glamorgan Record Office Cardiff, Dowlais Works, D/DG Sect. C Box 4;
(4) – (6) Valerius, Benoit, *Theoretisch-praktisches Handbuch der Roheisen-Fabrikation* (German by C. Hartmann), Freiberg 1851, pp. 474–478;
(7) Conseil supérieur de l'agriculture, du commerce et de l'industrie, *Enquête, Traité de commerce avec l'Angleterre, Industrie métallurgique,* vol. 1, Paris 1860, pp. 640 f.
(8) Archives Nationales Paris, F 12 2884, Rapport... sur le prix de revient de la fonte et du fer dans les usines du Département du Gard par M. Dupont, pp. 17 f.;
(9) *Reichs-Enquete für die Eisenindustrie 1878,* n.p. or d., p. 254;
(10) Wedding, Hermann, *Die Resultate des Bessemer'schen Processes für die Darstellung von Stahl und Aussichten desselben für die rheinische und westfälische Eisen- resp. Stahlindustrie,* in: Zeitschrift für das Berg-, Hütten- und Salinenwesen, 11 (1863), p. B. 265;
(11) Ministère de l'agriculture, du commerce et des travaux publics, *Enquête sur l'application du décret du 15 février 1862, relatif à l'importation en franchise temporaire des métaux,* Paris 1867, p. 215;
(12) *Report of the Commissioners appointed to inquire into the several matters relating to Coal in the United Kingdom,* vol. 1, in: Parliamentary Papers, 18 (1871), p. 151.

Sources on Table 5:

GREAT BRITAIN, coke pig iron at Glasgow: Meade, Richard, *The Coal and Iron Industries of the United Kingdom,* London 1882, p. 741; Sering, *Geschichte,* p. 302. Hard coal, Annual average price of all exports: Mitchell, B. R. and Deane, Phyllis, *Abstract of British Historical Statistics,* Cambridge 1962, p. 483. Bar Iron at Liverpool: Griffiths, Samual, *Guide to the Iron Trade of Great Britain,* new ed., n.p. 1967, pp. 288 f.

BELGIUM, coke pig iron, national average: Reuss, Conrad et al., *Le Progrès Économique en Sidérurgie, Belgique, Luxembourg, Pays-Bas, 1830–1955,* Louvain 1960, p. 396. Hard coal: Stainier, Emile, *Histoire commerciale de la métallurgie dans le district de Charleroi de 1829 à 1867,* sec. ed. Charleroi 1873, Appendix VI; Commission Centrale de Statistique, *Exposé de la situation du Royaume de 1861 à 1875,* Brussels 1885, vol. II, p. 646. Bar Iron (i.e. "fers finis") and Rails: Reuss et al., *Progrès,* p. 400.

FRANCE, coke pig iron, bar iron ("gros fer, fer marchand"), rails: Compiled from the various issues of the French mineral statistics, Direction générale des ponts et chaussées et des mines, *Compte rendu des travaux des ingénieurs des mines pendant l'année...* (1833–1835), Paris 1834–1836; Ministère du commerce et des travaux publics, Direction générale des ponts et chaussées et des mines, *Résumé des travaux statistiques ...* (1835–1836), Paris 1836–1837; Ministère des travaux publies et du commerce, *Résumé des travaux statistiques de l'administration des mines en ...* (1837–1846), Paris 1838–1847; Ministère de l'agriculture, du commerce et des travaux publics, Direction des mines, *Résumé des travaux statistiques de l'administration des mines en ...* (1847–1872), Paris 1854–1877. Hard coal: Ministère des travaux publics, *Statistique de l'industrie minérale et des appareils à vapeur en France et en Algérie* pour l'année 1893, Paris 1894, diagramme 1.

GERMANY, RUHR, coke pig iron: Däbritz, Walther, *Entstehung und Aufbau des rheinisch-westfälischen Industriebezirks,* in: Matschoß, Conrad (ed.), Beiträge zur Geschichte der Technik und Industrie, 15, Berlin 1925, p. 1906. Hard coal: Holtfrerich, Carl-Ludwig, *Quantitative Wirtschaftsgeschichte des Ruhrkohlenbergbaus im 19. Jahrhundert,* Dortmund 1973, pp. 22f. Bar iron: Holtfrerich, *Quantitative Wirtschaftsgeschichte,* pp. 145f.

UPPER SILESIA: Jacobs, Alfred and Richter, H., *Die Großhandelspreise in Deutschland von 1792 bis 1934,* Berlin 1935, pp. 62f.

Sources on Table 6:

(1) Zeitschrift für das Berg-, Hütten- und Salinenwesen, 9 (1861), p. 14.
(2/3) Zeitschrift für das Berg-, Hütten- und Salinenwesen, 10 (1862), p. 170.
(4) *Reichs-Enquete,* p. 254.
(5) *Reichs-Enquete,* p. 272.
(6) Zeitschrift für das Berg-, Hütten- und Salinenwesen, 10 (1862), p. 167.
(7) See note (7) on Table 4.
(8) Reuss, et al., *Progrès,* p. 396.
(9)–(14) Ministère de l'agriculture, du commerce et des travaux publics, Direction des mines, *Résumé des travaux statistiques de l'administration des mines en 1860 à 1864,* Paris 1867.
(15) See note on Table 5.
(16) Archives Nationales, Paris, F 12 2513, copy from the Mining Journal.

Table A 1: Iron Production in Belgium (B), France (F) and Prussia (P), 1836-1870, thousands of metric tons and percentages

Year		Pig Iron Production 1000 tons	by coke or mixed fuel %	Bar Iron Production 1000 tons	by hard coal %
1836	B	101.4-115.8	67.5-71.5		
	F	308.4	15.0	210.6	47.3
	P	88.7		50.5	32.1
1837	B	118.1	72.1		
	F	331.7	15.9	224.6	51.0
	P	99.5	9.6	58.7	31.8
1842	B	81.3	90.8		
	F	399.5	25.6	284.8	61.1
	P	101.0	18.0	79.3	39.5
1847	B	248.4	89.5	80.9	
	F	591.6	42.6	376.7	74.3
	P	137.9		158.5	70.2
1848/1850	B	151.5	89.8	65.9	
	F	430.8	40.9	255.3	71.4
	P	126.7	22.7	117.8	59.3
1851/1860	B	274.3	95.7	143.1	
	F	780.0	58.6	480.0	79.9
	P	305.5	38.3	239.8	85.4
1861/1870	B	442.2	99.2	358.8	
	F	1191.5	84.1	767.0	90.6
	P	819.9	91.5		

Notes and sources on Table A 1: The bar iron production includes rails. For Belgium this category represents total wrought iron production. The years were chosen according to information available for Prussia. On France and partly Belgium more information is published in the cited sources.

Belgium: 1836, 1837, 1842, own estimate based on the number of furnaces in blast. For the calculation methods see Fremdling, Rainer, *Untersuchungen zur Modernisierung der Eisenindustrie in Westeuropa 1820-1860,* manuscript 1982.

For the other years, Statistique générale de la Belgique, *Exposé de la situation du Royaume, 1841-1850, 1851-1860, 1861-1875,* Brussels 1852, 1865, 1885.

France: All years are covered, in: Ministère de l'agriculture, du commerce et des travaux publics, Direction des mines, *Résumé des travaux statistiques de l'administration des mines en ... (1847-1872),* Paris 1854, 1861, 1867, 1874, 1877.

Prussia: On pig iron production see Marchand, Hans, *Säkularstatistik der deutschen Eisenindustrie,* Essen 1939, pp. 39, 88; on the production by charcoal for 1837, 1842, 1849 see Oechelhäuser, Wilhelm, *Vergleichende Statistik der Eisen-Industrie aller Länder und Erörterung ihrer ökonomischen Lage im Zollverein,* Berlin 1852, p. 35; for 1848 see Althans, E., *Zusammenstellung der statistischen Ergebnisse des Bergwerks-, Hütten- und Salinenbetriebes in dem preußischen Staate während der zehn Jahre von*

Table A 2: French Iron Imports, 1815–1828, thousands of metric tons and percentages

Year	Bar Iron (fer en barres) tons	from Great Britain %	Belgium %	Sweden/Norway %
1815	6.9			
1816	4.0			
1817	13.8			
1818	10.1			
1819	10.7			
1820	8.9	76.8	10.1	?
1821	13.8	79.2	4.9	?
1822	5.1	48.5	8.1	37.1
1823	4.5	33.7	6.7	53.9
1824	5.8	17.7	3.0	67.1
1825	6.1	?	?	?
1826	9.6	?	?	?
1827	7.3	6.7	0.7	74.3
1828	6.6	15.9	0.3	72.3
	Pig Iron (fonte brute)			
1815	0.9			
1816	2.3			
1817	2.8			
1818	3.4			
1819	2.7			
1820	5.4			
1821	7.7	35.6	42.0	-
1822	8.3	30.7	41.5	-
1823	7.8	41.7	39.0	-
1824	7.2	24.9	47.4	-
1825	7.4	?	?	-
1826	11.4	?	?	-
1827	7.8	28.6	46.1	-
1828	8.8	29.9	44.2	-

All figures are related to the "commerce spécial", i.e. imports entering the French market for consumption.

1852 bis 1861, in: Zeitschrift für das Berg-, Hütten- und Salinenwesen in dem preußischen Staate, Suppl. to vol. 10 (1863) p. 85; for 1850 see Oechelhäuser, Wilhelm, *Die Eisenindustrie des Zollvereins in ihrer neueren Entwicklung,* Duisburg 1855, p. 14; for 1851–1870 see Marchand, *Säkularstatistik,* p. 39.

On bar iron production see Marchand, *Säkularstatistik,* p. 88; on the production by hard coal for 1836 see Marchand, *Säkularstatistik,* p. 37; for 1837, 1842, 1847–1860 see Althans, *Zusammenstellung,* p. 101.

Sources on Table A 2:

Ministère du Commerce et des Manufactures, *Enquête sur les fers,* Paris 1829, pp. 21, 23; Douanes Royales de France, *Tableau des quantités et de la valeur approximative des marchandises étrangères importées en France pour la consommation pendant l'année...,* Paris..., Years 1820–1824; Administration des Douanes, *Tableau général du commerce de la France avec ses colonies et les puissances étrangères, pendant l'année...,* Paris..., Years 1825–1828; Archives Nationales, F 12 2513.

Table A 3: British Iron Exports to France, 1815–1828

Year	Bar Iron		Pig Iron	
	1000 of metric tons	as percentage of total exports	1000 of metric tons	as percentage of total exports
1815	0.09	0.5	-	-
1816	1.1	5.3	-	-
1817	11.8	34.3	0.8	19.9
1818	8.8	20.8	0.9	27.8
1819	5.3	22.3	0.2	16.6
1820	7.7	21.1	1.4	52.0
1821	11.4	33.7	3.1	68.1
1822	2.6	7.6	3.4	66.1
1823	2.4	7.1	4.1	53.1
1824	1.4	5.5	0.9	43.7
1825	1.5	5.9	1.1	37.7
1826	2.7	8.0	3.9	58.3
1827	1.7	3.8	2.7	37.8
1828	2.1	4.1	2.2	28.4

Exports to Ireland, the Isle of Man and to the Channel Islands were subtracted from total exports.

Source: *Parliamentary Papers,* 1819, vol. XVI; 1825, vol. XXI; 1829, vol. XVII.

Zusammenfassung: Außenhandelsstruktur, technischer Wandel, Kosten und Produktivität in der Eisenindustrie Westeuropas, 1720–1870

Dieser Aufsatz ist Teil eines umfassenderen Projektes, in dem die Diffusion des Koksschmelzens und des Puddelverfahrens in Belgien, Frankreich und Deutschland von den 1820er Jahren bis in die 1860er Jahre untersucht wird. Großbritannien als wirtschaftlich führendes Land in der Eisenindustrie ist darin vorrangig in seiner Modellfunktion sowie als Exporteur primärer Eisenprodukte (Roh- und Stabeisen) einbezogen. Wesentliches Anliegen der Arbeit ist, den Diffusionsprozeß aus *ökonomischen* Erwägungen zu erklären. Damit soll der gängige Fehler vermieden werden, technische Fortschritte verkürzt mit wirtschaftlichen gleichzusetzen. Traditionelle Verfahren oder teilweise modernisierte Techniken waren nämlich lange Zeit den jeweils „modernsten" Techniken unter *wirtschaftlichen* Gesichtspunkten (d. h. hinsichtlich der Produktionskosten) durchaus ebenbürtig.

Aus der umfangreicheren Themenstellung werden hier zwei Teilbereiche herausgegriffen, und zwar:

1. Strukturwandlungen des Außenhandels,
2. Produktivitätsentwicklungen im Vergleich von Regionen bzw. Ländern.

Die Strukturwandlungen des Außenhandels (Punkt 1) wurden zwischen Frankreich und Deutschland verglichen. Als ausgeprägte Unterschiede erwiesen sich dabei die Zollpolitik und die Rolle von Importen. In Frankreich ermöglichten hohe Zolltarife einen verzögerten, langgezogenen Übergang zur Steinkohlentechnologie, wobei man stärker auf vorhandene inländische Ressourcen zurückgriff. In Deutschland dagegen bewirkten die niedrigen Zolltarife einen schnellen und eher abrupten Wechsel, wobei in beträchtlichem Ausmaß Zwischenprodukte (Roheisen) von außerhalb eingesetzt wurden. In den späten 1850er Jahren hatten beide Länder in der primären Eisenindustrie ungefähr den gleichen technischen Standard erreicht. Die Produktionskosten waren dann so weit gesenkt, daß man sich die niedrigen Zolltarife im Rahmen des Cobden-Chevalier-Vertrages leisten konnte.

Unter Punkt 2 wurde versucht, die Produktivitätsentwicklung bei der Herstellung von Roheisen und Stabeisen zu messen, indem die Outputpreise dem Preis des wichtigsten Inputs (nämlich Steinkohle für das Roheisen und Roheisen für das Stabeisen) im Trend gegenübergestellt wurden. In der Roheisenerzeugung zeigten die kontinentaleuropäischen Länder in der Zeit zwischen 1845/1850 und 1870 deutlich höhere Produktivitätsfortschritte als Großbritannien. In der Stabeisenherstellung dagegen, d. h. beim Puddel- und Walzprozeß, wiesen alle Länder kaum Produktivitätsfortschritte auf. All diese Kosten- und Preisvergleiche zeigen aber, daß Großbritannien in den 1860er Jahren immer noch der Anbieter zu niedrigsten Preisen war, wenngleich kontinentaleuropäische Eisenproduzenten inzwischen so weit aufgeholt hatten, daß sie unter dem Schutz der noch immer existierenden Zolltarife und der Transportkosten ihr Eisen in ihren Ländern ebenso billig, wenn nicht gar billiger anzubieten vermochten.