PROBLEMS

German non Ferrous Metal Production in the Early Nineteenth Century *

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I.

Problems of assessing rates of German industrial expansion in the early nineteenth century are hindered by a lack of readily available production statistics. Relatively comprehensive data are available from 1848.[1] Before this only occasional indications of total production are available. Some sectors of industry, however, present partial exceptions to this situation. One of these is the non-ferrous metal industry where reasonably reliable estimates of production are available each year from 1823.[2] Before then, even in these industries, data of total and regional production are scanty, and partial contemporary estimates must be relied upon to a large extent. There is one exception though. In 1807 a French engineer made a detailed study of the German mining and metallurgical industries[3] and from this it is possible to piece together some of the woefully inadequate picture of progress in these industries at the beginning of the nineteenth century.

* My thanks are due to Prof. W. E. Minchinton, Dr R. Burt and Mr R. A. Lewis for reading and commenting on a draft of this paper. Any errors or shortcomings that remain are entirely my own.

1 GEORG VON VIEBAHN (ed.), *Statistik des Zollverein und nördlichen Deutschlands*, 3 vols. (Berlin, Reimer: 1858-68), continued as KAISERLICHEN STATISTISCHEN AMT., *Statistik des deutschen Reichs* (Berlin: 1873-79) and *Statistische Jahrbuch für das deutsche Reich* (Berlin: 1880 ff.).

2 C. J. B. KARSTEN (ed.), *Archiv für Bergbau und Huttenwesen* (Berlin, Reimer: 1818-26), and *Archiv für Mineralogie, Geognosie, Bergbau und Hüttenkunde* (Berlin, Reimer: 1829 ff.).

3 ANTOINE MARIE HÉRON DE VILLEFROSSE, *De la Richesse Minérale: Considérations sur les mines, usines et salines des différents états*, 3 vols. (Paris, Levrault: 1819).

In the previous three centuries, mining and metal working in Germany had passed through a number of fluctuations, with alternating prosperity and depression. During the late middle ages it had reached a peak of activity and Germany had exported miners and technology all over Europe.[4] There had been a long period of decline from the end of the sixteenth century and a revival in the mid-eighteenth century, to a certain extent fostered by the expansive economic policies of Frederick the Great.[5] Mining and manufacturing industries in different regions fared unevenly though, and entered the nineteenth century with a mixture of old and new technology and, where developed, remained small enclaves in areas largely untouched by material progress.

During the course of the nineteenth century, with production levels known after 1823, the increasingly rapid growth of the German metal industries can be measured. By the 1880s and 1890s Germany was the world's largest producer of zinc, its second or third producer of lead, and the third or fourth producer of copper.[6] Undoubtedly the development of the non-ferrous metal industries on such a scale played no small part in the rise of industrial Germany, providing a ready supply of these essential industrial raw materials.

The aim of this short study is to utilise the production estimates of 1807 and such other fragments of data as exist, in conjunction with the statistics available after 1823, in order to suggest a chronology of growth in this sector of the German economy during the period from the 1790s to the 1830s and 40s. It may then be possible to see this suggested chronology in relation to two wider, and as yet unresolved problems: explaining the initial slow progress of the industrial revolution in Germany and in discussing the economic effects of the Napoleonic war period.[7]

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[4] T. K. Derry and T. I. Williams, *A Short History of Technology* (Oxford: 1960), pp. 128-143.

[5] W. O. Henderson, *The State and the Industrial Revolution in Prussia, 1740-1870* (Liverpool: 1958), pp. 9-20.

[6] Bernhard Neumann, *Die Metalle: Geschichte, Vorkommen und Gewinnung* (Halle, Knapp: 1904), pp. 112-113, 150-151, 314-315; in the period 1881-85 average annual German production of crude zinc was 118.0 thousand tonnes, compared with 75.1 for Belgium and 32.7 for the United States, the next biggest producers. In the same period, Germany's figure for lead was 91.5 thousand tonnes, compared with 120.3 for the United States and 90.0 for Spain. The equivalent figures for crude refined copper were: Germany 17.4 thousand tonnes, United States 53.0, Chile 35.2, and Spain 33.2. By 1886-90, Chile had fallen to fourth place behind Germany.

[7] On these problems see, David S. Landes, *The Unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present* (Cambridge: 1969), pp. 142-144; Tom Kemp, *Industrialisation in Nineteenth Century Europe* (Longmans: 1969), pp. 84-95; Alan S. Milward and S. B. Saul, *The Economic Development of Continental Europe, 1780-1870* (Allen and Unwin: 1973), pp. 267-270,

II.

The geographical basis of German non-ferrous metal production changed little between the early eighteenth century and 1850.[8] There were three main areas of production.[9] First, there was a broad belt running through the provinces of the Rhineland and Hesse in the west of the country. In the vicinity of Aachen and Stolberg were a number of long-established but underdeveloped lead and zinc mines, refineries and brass works.[10] To the south-west, running down the Rhine from Bonn, through Koblenz, to Wiesbaden, were a number of lead mines and manufacturing works.

The second area ran in another broad belt, through the provinces of Westphalia, Hanover and Saxon-Thüringia, to end in the Erzegebirge, on the border between Saxony and Bohemia. In the north of this belt, in the province of Hanover, was located a lead mining district around Hildesheim. South of this there was an ancient and once important mining centre in the Harz mountains, near Goslar and Clausthal. A large number of lead, silver, copper, and zinc mines was complemented by an even larger number of manufacturing establishments producing lead sheets and pipes, copper sheets, pipes and wire, and brass.[11] Most of these establishments were small and existed on the same technological basis as they had done for three centuries.[12] Further south-west, on the edge of the Thüringia Wald, near Eiselben and Sangerhausen, were the most productive copper mines in Germany, those of Mansfeld. In the locality were a number of copper

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301-304, 365-385; SIDNEY POLLARD, *Industrialisation and the European Economy*, « Economic History Review », 2nd. ser., XXVI, p. 4; (1973), pp. 636-648; RONDO CAMERON, *France and the Economic Development of Europe, 1800-1914* (New Jersey, Princeton: 1961), pp. 52-55; FRANÇOIS CROUZET, *Wars, Blockade and Economic Change in Europe, 1792-1815*, « Journal of Economic History », XXIV (1964), pp. 567-588.

[8] It had probably changed little since the peak of activity in the 16th. century. On the technological basis of German mining and metallurgy in this earlier period see, GEORGIUS AGRICOLA, *De Re Metallica* (Basel: 1556; reprinted Hoover ed. New York, Dover: 1912, 1950), a classic work by a doctor in the Saxon mining district.

[9] In addition there was a relatively unimportant mining district in the Bavarian Tyrol, and a small but strategically important metal and munitions industry centred on Berlin and Brandenberg. On the latter see, W. O. HENDERSON, *Studies in the Economic Policy of Frederick the Great* (Cass: 1963), pp. 1-16, « The Rise of the Metal and Armaments Industries in Berlin and Brandenberg ».

[10] The Aachen brass industries had been established as early as the 12th century; RUDOLPH PELTZER, *Geschichte der Messingindustrie* (Aachen, Cazin: 2nd ed., 1909), pp. 33-45.

[11] ANON., *Itinéraire de l'Allemagne* (Amsterdam, Covens: 1805), pp. 203-204.

[12] During the period 1801-1807 in the Harz mining district a total of 94 water wheels were in use in mines, but only one steam engine, that at the Rothenberg copper mine: VILLEFROSSE, *op. cit.*, pp. 27- 102.

and brass manufacturing works.[13] Finally, in the south, there was the long established mining district of the Erzegebirge, in Saxony.[14] Centred on the old mining towns of Zwickau, Altenberg and Freiberg, this large and mountainous district produced tin, copper, lead and silver in rather irregular amounts.[15]

The third and last area was situated in the east of Germany, in territory seized from the Austrians in 1742. There, in Upper Silesia, a small but expanding zinc and lead industry was established in the neighbourhood of Scharley, Gleiwitz, Tarnowitz and Königshütte.[16] The success of the industries in this region was not only due to the abundance of zinc and lead ores, but also to cheap local fuel contained in what was later realised to be the largest coal-field in western Europe.[17]

III.

During the reign of Frederick the Great (1740-86) economic policy had been primarily aimed at consolidating the position of the state. To this end certain strategic industries had been encouraged, among these the producers of non-ferrous metals. However, as has been pointed out recently,[18] « when Stein began his reforms of the mining laws of the county of Mark... (he was) the harbinger of a changed mercantilism... » Frederick's ministers, Stein and Von Reden certainly did much to induce an increase in output of copper, lead and brass to feed the munitions works of Berlin and Brandenberg, as Henderson has suggested.[19] However, the aims of the state were not specifically seen as encouraging industries *per se,* and that encouragement often merely consisted of « providing the necessary basis for development, the social overhead capital, as creating the right

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13 W. P. Jervis, *The Mansfeld Copper-Slate Mines... their Past and Present State...*, « Journal of the Society of Arts », IX (1861), pp. 592-632. These mines were generally held to have been commenced in 1199.

14 Probably first worked by the Romans and certainly one of the oldest centres of mining in Europe; see O. Davies, *Roman and Medieval Mining Technique*, « Transactions of the Institute of Mining and Metallurgy », XLIII (1934), pp. 3-54. This mining district had been the home of Agricola (George Bauer), author of *De Re Metallica*, and formed the background for his classic work.

15 Edmund Spenser, *Sketches of Germany and the Germans in 1834*, 2 vols. (Whittaker: 1836), I, pp. 280-281 gives an account of this area.

16 Henderson, *State and the Industrial Revolution*, op. cit., chapter 1.

17 See Norman J. G. Pounds, *The Upper Silesian Industrial Region* (Indiana U. P., 1959), and Gustav Felsch, *Die Wirtschaftspolitik des preussischen Staates bei der Gründung der oberschlesischen Kohlen- and Eisenindustrie 1741-1871* (Berlin: 1920).

18 Milward and Saul, *op. cit.*, p. 417.

19 *State and the Industrial Revolution, Studies in the Economic Policy of Frederick the Great.*

atmosphere and then withdrawing from the arena ».[20] The legacy for early nineteenth-century German metal production of Frederick's policies was a product of this watered-down mercantilism.

Having eased the path of producers with the potential and will to expand, the ministers of the state left the stage, and the actual pattern of development became more of a function of general economic conditions. Where availability of capital, technology and a ready market existed, the result was modest expansion. In other areas, industries lacked these necessary conditions, and growth was negligible. Data of production for the late eighteenth century is almost non-existent, but such glimpses as are available seem to indicate that growth in the non-ferrous metal industries was at very different rates in various parts of Germany.

The two areas to receive most attention and success in terms of increased output were Silesia, with its largely untapped coal, iron, zinc and lead resources, and Berlin-Brandenberg with its armaments and munitions industries. In the case of the former, economic development had followed on from territorial conquest, and in the case of the latter, it had helped provide the means to consolidating that conquest. Other mining and metal manufacturing areas in Germany fared less well, though. During the eighteenth century Prussian influence had spread through the German states fairly rapidly; first Saxony was annexed and later Westphalia and Hanover came increasingly within the Prussian sphere.[21] The looseness of Frederick's policy within his circle of influence and the multiplicity of ineffectual states outside perpetuated the situation of uneven development. It can be suggested quite confidently that Frederick's policies and latent economic conditions in conjunction did little more than create a few modernised enclaves within a largely stagnating economy. In terms of non-ferrous metal production, apart from the Silesian and Brandenberg industries, total output probably grew little in the closing stages of the eighteenth century.

Contemporary estimates of production that exist for some districts suggest that until about 1805 or 1806 non-ferrous metal output was growing very slowly in some areas and contracting in others. The two ancient mining areas of the Erzegebirge and the Harz[22] had both reached a peak of productiveness in the late sixteenth century and had then declined. The ravages of the Thirty Years War had all but destroyed the Mansfeld mines.[23] There had been a slight recovery in the third decade of the eighteenth century but by the end of the 1780s output had slumped again.

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[20] MILWARD and SAUL, *op. cit.*, p. 417.

[21] See, W. F. REDDAWAY, *Frederick the Great and the Rise of Prussia* (Putnam: 1925).

[22] Both of these areas had come under the administration of the Prussian mining office in Berlin before 1786; VILLEFROSSE, *op. cit.*, p. 13.

[23] JERVIS, *loc. cit.*, p. 605.

A French visitor commented in 1805: [24]

> At Clausthal... the richest mines are the *Caroline*, which is 105 fathoms in depth, and the *Dorothy*, which is 102 fathoms. The *Caroline* mine produced, in each quarter of 1785, 54 crowns, and the *Dorothy* 40 crowns. However, neither of these are now producing so great a yield as they did originally, when the produce of the *Dorothy*, for example, was an average of 110 crowns per quarter for 67 quarters in succession. In 1785, each week at Clausthal, 600 marcs of silver (300 lbs) were minted... worth a total of 374,000 crowns a year. In former years the annual output of money minted in this town amounted to 400,000 or 500,000 crowns.

Another French visitor, Héron de Villefrosse, visiting the Harz mines in the year 1803, commented on the decline of the establishments during the late eighteenth century, and included a table of output:

TABLE 1

VALUE OF MINERAL PRODUCTION IN THE CLAUSTHAL AND ZELLERFELD MINES, HARZ MOUNTAINS, 1700-1803
(*Thalers*)

	Clausthal District	Zellerfeld District
1700	85,973	18,277
1734	133,813	46,790
1770	67,253	5,849
1790	76,960	...
1800	53,733	...
1802	49.920	...
1803	49.573	...

Source: VILLEFROSSE, *op. cit.*, p. 81.
Note: Zellerfeld figures, 1790-1803, not available.

In commenting on the weak state of the Harz mining and metal manufacturing work, Villefrosse indicated that a large number of them were working on the margins of profitability, or at a loss. They were only kept solvent by royal subsidies and artificial price levels.[25]

In other mining districts output grew slowly at the end of the eighteenth century. At the Mansfeld copper mines the average annual production of fine copper during the period 1741-61 had been just over 400 tonnes. In the period 1780-1804 this had increased to about 700 tonnes.[26] In the vicinity of Aachen and Stolberg the under-developed lead and zinc resources were to wait until the 1840s, and French intervention,

[24] *Itinéraire de l'Allemagne*, op. cit., pp. 202-203.
[25] VILLEFROSSE, *op. cit.*, pp. 103-104.
[26] NEUMANN, *op. cit.*, p. 110.

before full exploitation became a reality.[27] Of all the mining districts only in Silesia were the first signs becoming apparent of a modern technologically based industry, utilising the locally abundant coal, zinc and lead deposits.

As early as 1704 a Breslau merchant, Georg von Giesche, was granted a lease from the Counts of Henckel, the local landowners, to extract and trade in Silesian calamine.[28] This lease was extended in 1782,[29] the *Georg von Giesches Erben*[30] being well-established in the trade by this date.[31] However, the Silesian zinc industry as a whole had changed little. The local production of calamine was largely exported, only a little being used in the manufacture of brass, by traditional methods, at Breslau, Gleiwitz and Tarnowitz.[32] There had been some developments in the lead industry. By 1789 a modern lead-smelting furnace, using coke as fuel, was in operation at Friedrichshütte.[33] However, the future of the Silesian non-ferrous metal industries lay mainly with zinc,[34] and this sector did not receive a fundamental change in its technological basis until right at the end of the eighteenth century.

Between 1780 and 1789, annual production of calamine in Silesia averaged 500 tonnes. By 1792 this had increased to 900 tonnes.[35] The local reducing of the ores into spelter (metallic zinc) commenced in 1798 or 1799, when Johann Christian Ruberg, a gold merchant of Pless, introduced the process he had seen during a visit to England.[36] His first furnace was situated at Glashütte, near Wessola.[37] Within a few years others were

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27 See RONDO CAMERON, *Some French Contributions to the Industrial Development of Germany, 1840-1870*, « Journal of Economic History » XVI (1956), pp. 281-321, and « France and the Economic Development of Europe », *op. cit.*

28 WALTER INGALLS, *Production and Properties of Zinc* (New York, Mining Journal: 1902), p. 7. Calamine is carbonate of zinc. Prior to the perfection of an industrial process to isolate metallic zinc, by John Champion of Bristol in 1740 (Ingalls, p. 7) all brass was manufactured by mixing copper and calamine in a furnace. This practice continued for some time after this date but had generally been replaced by the process of fusing metallic zinc and copper by the 1830s.

29 LEOPOLD VON WIESE, *Beiträge zur Geschichte der wirtschaftlichen Entwicklung der Rohzinkfabrikation* (Frankfurt, Merker: 1902), p. 38.

30 i. e., the « Georg von Giesches Company » (literally « inheritance »).

31 See WILHELM TREUE, *Georg von Giesches Erben, 1704-1964* (Cologne: 1964).

32 WIESE, *op. cit.*, p. 38.

33 W. O. HENDERSON, *Britain and Industrial Europe, 1750-1870* (3rd. ed., Leicester U. P.: 1972), pp. 153-154.

34 In the period 1848-1857 annual average Silesian output of zinc ore was 158.5 thousand tonnes, and of lead ore 2.9 thousand tonnes (VIEBAN, *op. cit.*, II, pp. 379, 382).

35 INGALLS, *op. cit.*, p. 7.

36 INGALLS, *op. cit.*, pp. 7-8, and WIESE, *op. cit.*, pp. 27-30. Ruberg had modified the process he saw at Bristol, virtually inverting the English arrangement of furnace and retort, resulting in the distinctive process thereafter known as the Silesian method of zinc distillation.

37 WIESE, *op. cit.*, p. 38.

established at Friedrichshütte and Königshütte.[38] By 1802 the *Georg von Giesches Erben* was refining zinc by the « Silesian » process at Scharley, Schoris and Trockenberg.[39] The result of this activity was that in the period 1800 to 1808 and estimated total of 1400 tonnes of spelter was produced in Upper Silesia.[40] At the time this probably represented about 20 per cent of the entire European output of the metal,[41] the remainder coming from England and the Moresnet region between Belgium and Germany.

The net result of state policies to the end of the eighteenth century designed to stimulate production would seem to have been mixed. By the beginning of the nineteenth century such growth as had occured was virtually limited to certain « high-spots » of economic activity, recognised in a recent synthesis by Pollard.[42] Total production of the non-ferrous metals by the turn of the century was also probably little greater than in the 1720s and 30s.

IV.

With the advent of the Napoleonic Wars,[43] a paradoxical situation developed. While it is likely that the disrupting effects of warfare were retarding economic development as a whole in Germany,[44] the war also acted as a stimulus to some forms of production. Belligerent armies and navies needed an increasing supply of largely expendable munitions. In these circumstances, governments actively encouraged the production of « war materials », and, in particular, ferrous and non-ferrous metals.[45]

In the German states, further stimulus to production in the non-ferrous metal industries came in the wake of the French invasions of the Rhineland and Westphalian provinces in 1803, and of Saxony and Prussia in 1806. From then until their withdrawal in 1813-14, the French involved themselves

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[38] INGALLS, *op. cit.*, p. 8.

[39] WIESE, *op. cit.*, p. 38.

[40] NEUMANN, *op. cit.*, p. 313.

[41] Total world production of spelter in the year 1800 has been estimated at about 1000 tonnes: Metallgesellschaft, *Collected Statistics of Mineral Production...* (Frankfurt-am-Main): 1956), p. 227.

[42] *Industrialisation and the European Economy*, loc. cit., p. 638.

[43] Properly 1793-1815. However the main period of French influence within Germany was from 1797 and the Treaty of Campo Formio, which ceded them much of the Rhineland, until the beginnings of withdrawal in 1813. The French invasion of Prussia was in 1806-1807.

[44] See CROUZET, *loc. cit.*, esp. 585, and LANDES, *op. cit.*, pp. 142-143.

[45] In *War and the English Economy 1700-1763*, « Economic History Review », 2nd ser., VII (1955), pp. 330-331, A. H. JOHN suggests that the British non-ferrous metal industries underwent a similar expansion during wartime conditions at an earlier stage in the eighteenth century.

in fostering sections of German industry. Teams of engineers, geologists and factory inspectors from the invading country were detailed to visit the German states, report on the state of their industries and make suggestions for their improvement.[46]

As regards non-ferrous metal mining and manufacturing, the French had a special interest in fostering these industries. Rondo Cameron has argued that a lack of mineral resources within their own country stimulated Frenchmen to exploit those in Germany at a later stage in the nineteenth century.[47] During the Napoleonic Wars, with British blockade making the normal shortage more severe, it became of the utmost importance for French engineers and geologists to examine the available resources in the invaded lands.[48] A steady supply of copper, lead and brass to French munitions works was all the more necessary since that country's principal enemy had an adequate domestic supply of these materials.[49]

Accordingly, a large number of members of the *Corps royal des mines de France*, engineers and geologists, were installed in the German mining areas.[50] Among these was Antoine Héron de Villefrosse, a graduate of the school of mines in Paris. He later noted that he had been charged in 1803 to « look at the state of the mines and metal manufactories of the Harz... in the capacity of an engineer-commissary of the French government... and to collect and send to the Minister of Mines in France the most detailed information on these celebrated establishments ».[51] The result was later to be published as one of the most detailed studies of German mining and metal working to be published since the classic work of Gabrielle Jars had appeared, forty years previously.[52]

The exact role and methods of the *Corps royal* is not clear, but it would appear that if Villefrosse was a typical member, it probably worked in harmony with German mine-owners and metal manufactures, particularly in the western provinces; the Rhineland and Westphalia. These latter areas were under an increasing degree of French influence from 1797, as opposed to the eastern provinces such as Upper Silesia, which only came under full

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46 « Economic Development of Europe », Rondo Cameron, *op. cit.*, pp. 55-56.

47 *Ibid.*, p. 375.

48 In Spain the French had tried to exploit the vast copper resources of the Rio Tinto mines. In December 1810 French troops seized all stocks of copper there. Otherwise the attempt was a failure due to the uncooperative nature of the Spaniards. W. G. Nash, *The Rio Tinto Mine: its Romance and History* (Simpkin Marshall: 1904), pp. 163-165.

49 With its Cornish and Anglesey copper, and Welsh and Pennine lead, Britain had a virtual European monopoly in the production of non-ferrous metals before the 1830s and 1840s.

50 Villefrosse, *op. cit.*, pp. i-xiv.

51 *Ibid.*, p. i.

52 *Voyages Metallurgiques*, 3 vols. (Paris and Lyons: 1774-1781).

French control after the Prussian defeat at Jena in 1806. The French do not seem to have achieved the same degree of cooperation from the Silesian zinc and lead producers, and Neumann notes that from the end of 1808 an increasing amount of partisan activity in the area around Königshütte resulted in a disruption of production and some actual destruction of plant.[53]

In the Rhineland and in Westphalia, the latter Villefrosse's area, on the other hand, a tradition of cooperation seems to have been forged which later came to fruition in the 1840s and 50s, when numerous French companies were to finance and organise large scale non-ferrous metal production.[54] In these areas German producers undoubtedly benefitted from a combination of circumstances favourable to production: during the period 1802-13 they received encouragement from the French authorities to increase output — this may have come in terms of various concessions from the invaders — and individuals like Villefrosse would have been available with their technical knowledge, and links with markets in France. These French markets were of inestimable importance, as Cameron has already tentatively suggested.[55] Merely in terms of population, in 1800 France was the largest single potential market in Europe; 26.9 million people compared with 10.9 million in Britain, and a total of 24.5 million million scattered throughout the German states.[56] The importance of the availability of the French market to Germany was greater that these figures suggest, though. In peace-time, French industry, highly sophisticated compared to that in Germany, had relied to a great extent on the importing of ferrous and non-ferrous metals from Britain. The war situation changed all this and created a new trading situation within Europe. It has recently been suggested that later, in the 1830s in Germany « the Zollverein was a deliberate attempt to restore the larger markets which the ' continental system ' had so briefly created. The destruction of that system in 1814 had meant the collapse of the new trade routes which Napoleon's re-drawing of the map of Europe had created. The continental system had reversed the long relative decline of German industry and in the Rhineland and Saxony had even produced the first stirrings of the German industrial revolution ».[57]

With the French naval ordnance works at Brest, Nantes and Bordeaux, and military munitions works at Paris demanding more and more raw materials, over and above the immediate levels of supply, prices of non-

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[53] *Op. cit.*, p. 298.

[54] CAMERON, *Some French Contributions*, loc. cit., pp. 284-295.

[55] CAMERON, « Economic Development of Europe », *op. cit.*, p. 54.

[56] Population figures from, ANDRÉ ARMENGAUD, *Population in Europe, 1700-1914*, « Fontana Economic History of Europe », III, 1 (Collins, 1973), p. 29.

[57] MILWARD and SAUL, *op. cit.*, p. 372.

ferrous metals rose in France and Germany. Between 1796 and 1808 the price of refined copper doubled, as did the price of pig lead and crude refined zinc (see table 2). These higher prices themselves would seem to have acted as a stimulus to production.

TABLE 2

NON-FERROUS METAL PRICES IN GERMANY, 1780-1820
(*marks/tonne*)

Annual average	Copper [a]	Lead [b]	Zinc [c]
1781-1785	1,550	...	880 [d]
1786-1790	1,390	294 [e]	960 [f]
1791-1795	1,360	341	...
1796-1800	1,580	360	1,920 [g]
1801-1805	1,800	376	840 [h]
1806-1810	2,700 [i]	458 [j]	800 [k]
1811-1815	2,500	499 [l]	455 [m]
1816-1820	2,000	461 [o]	302 [p]

Sources:

Copper prices: NEUMAN, *op. cit.*, p. 118.
Lead prices: *ibid.*, p. 153.
Zinc prices [d, f, g, k]: VILLEFROSSE, *op. cit.*, p. 59; [h, m, p]: NEUMANN, *op. cit.*, p. 319.

Notes:

[a] Copper prices at Mansfeld.
[b] Lead prices at Tarnowitz.
[c] Prices in Silesia unless otherwise stated.
[d] 1780 price in Harz district.
[e] 1787-1790 average.
[f] 1790 price in Harz district.
[g] 1800 price in Harz district.
[h] 1805 price.
[i] Maximum 2,790 marks in 1808.
[j] Maximum 717 marks in 1810.
[k] 1807 price in Harz.
[l] Maximum 561 marks in 1813.
[m] Average 1814-1815 prices.
[o] Minimum 448 marks in 1818.
[p] Average 1816-1820 prices.

As far as statistics allow, it would seem that between about 1803 and 1813, from such areas as the French established viable business relations, the latter secured for themselves a fairly steady supply of lead, copper and brass. Villefrosse noted:[58]

> In 1805, the value of the mineral products of the German states rose to a sum of six million Reichsthalers... in the same year, the export of minerals and metals from Germany rose to 1,535,000 Reichsthalers, and the imports were 953,330 Reichsthalers. Thus the balance of trade, relative to mineral products, was to the advantage of the Germans to a sum of 581,670 Reichsthalers. Since 1786, the exportation of these minerals has nearly doubled, without the imports being augmented.

The growth in output seems to have continued after 1805. In that year Villefrosse had estimated total German mineral production at about 6 million thalers. By 1807 he suggested that it had risen to 9.3 million,[59] although

[58] p. 15.
[59] p. 240.

it is not possible to know whether he defined mineral production the same way in both cases. In any case this may be taken as a rough indication of a substained high level of mineral production.[60]

An example of the way in which the output of individual districts was increasing is given by Villefrosse in an account of the Mansfeld copper works:[61]

> There exist, in the Saxon territory, three copper works near Mansfeld: two near Eiselben and one at Sangerhausen. Another, called the *Kupferkammerhütte* is situated nearby, to the east... Lastly, a great refining works is located near Hettstädt... in turn supplying copper to all the Saxon manufacturing establishments. In 1801 the Hettstädt works produced about 8,000 quintals of copper and 12,000 marcs of silver. By the year 1807 the output of these works had increased to nearly 11,000 quintals of copper and 15,000 marcs of silver... Nevertheless, the manufacture of the year 1807 cannot be regarded as normal...

The abnormal level of production in 1807 was brought about, Villefrosse suggested,[62] by the wartime demand and the activities of his compatriots.

From an estimate that Villefrosse made of total German production of non-ferrous metals in 1807 (see table 3) it seems likely that this year's output represented something of a peak in the fluctuating fortunes of the industries. Comparison with the official estimates of production for the period after 1823 (see table 4) is not straightforward, but does suggest that, apart from zinc,[63] post-war output did suffer a marked setback.[64] In fact, allowing for the undoubted inadequacies of all these statistics, it is possible that the 1807 production levels of copper and lead were not regained until about 1840.

Some specific problems arise when attempting to make a comparison between the 1807 estimates and the official figures after 1823. These arise

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[60] There is always a possibility that Villefrosse may have engineered a biased view of French achievements in terms of increased output. However, this seems fairly unlikely on two grounds: first, he always insisted his figures came from « official registers » (p. 102), and secondly, he was an engineer much respected by the Germans and he himself was full of praise for the achievements of Frederick's administration in stimulating the mining industries (p. 15). During the war period he was « supervisor of the Harz mines » 1803-1805, « inspector-general of the mines between the Rhine and the Vistula » 1807-1809, and « director of the mining establishment of the Kingdom of Westphalia » 1809-1814 ». After the war he was decorated by the Prussian government for his services to industry; CAMERON, *France and Economic Development*, p. 55.

[61] VILLEFROSSE, *op. cit.*, pp. 22-23.

[62] *Ibid.*, pp. 15, 23.

[63] On the zinc industry, only in its adolescence in this period, see E. A. SMITH, *The Zinc Industry* (Longmans: 1918), INGALLS and WIESE.

[64] British production of metals also slumped after 1815, for example lead production, in 1785, estimated at 45,000 tonnes, had fallen to 31,900 tonnes by 1822, although it had recovered to 47,000 tonnes by 1828.

TABLE 3

GERMAN PRODUCTION OF NON-FERROUS METALS BY REGIONS, 1807

PRUSSIA:	Silver,	2,460 marcs;	from Tarnowitz and Leuthen (Upper Silesia)
	Lead,	12,992 quintals;	Tarnowitz
	Copper,	337 quintals;	Kupferberg (Upper Silesia)
	Zinc,	7,879 quintals;	Tarnowitz
SAXONY:	Silver,	66,000 marcs;	Freiberg, Marienberg, Annaberg and Schneeberg (Erzegebirge)
	Lead,	10,000 quintals;	Freiberg, Marienberg, Annaberg and Schneeberg
	Copper,	10,320 quintals;	Mansfeld, Freiberg, Grünthal and Neustädt (Erzegebirge)
	Tin,	2,500 quintals;	Altenberg, Marienberg, Geyer and Ehrenfriedersdorf (Erzegebirge)
BAVARIA:	Silver,	3,500 marcs;	Schwatz (Tyrol)
	Lead,	400 quintals;	Schwatz
	Copper,	3,000 quintals;	Schwatz, Giorezzo and Sterzing (Tyrol)
WESTPHALIA:	Gold,	10 marcs;	Goslar (Harz)
	Silver,	39,710 marcs;	Harz and Frankenberg (Hesse)
	Lead,	59,771 quintals;	Clausthal, Altenau and Goslar (Harz), Hanover, Hesse and the Rhineland
	Copper,	8,229 quintals;	Rothenberg, Riegelsdorf (Hesse) Goslar and Lauterberg (Harz)
	Zinc,	1,200 quintals;	Goslar, Hesse
	(plus	52 quintals spelter;	Goslar)

Source: VILLEFROSSE, *op. cit.*, p. 240.

Notes:

1 marc equals 8 oz. The Prussian quintal equals about 110 pounds.
All weights given are of refined metal except zinc, which is given as calamine (see footnote 28).
The area of Prussia given is that after the Peace of Tilsit.

largely from the fact that German statistics of non-ferrous metal output, 1823-47 inclusive, are subject to a certain amount of error; returns of production not being available from all states until 1848. This has a minimal effect on zinc and copper figures but, at the levels of production of 1848, approximately 60 per cent of the lead and litharge (white lead oxide) originated in areas which made no returns before that year.[65]

[65] On the problems of assessing pre-1848 production statistics for non-ferrous metals, see W. G. HOFFMANN et al., *Das Wachstum der deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts* (Berlin, Springer: 1965), pp. 350-351.

Assuming this proportion to have been fairly constant over time, the 1823-47 figures in table 4 have been adjusted by this proportion to make them comparable with the 1807 figures, which do include production from those areas. Here, perhaps, lies the greatest value of the 1807 estimates. They were made at a time when Germany was artificially united under the continental system, and therefore were more complete than any following estimates until 1848, when Germany had at last started struggling its own way to some form of economic and political unity.

TABLE 4

GERMAN NON-FERROUS METAL PRODUCTION, 1807-1850
(*tonnes*)

Annual average	Copper	Lead	Zinc
1807	1,094.4	4,158.2	320.3 *
1823-1825	777.6	3,724.8	10,435.0
1826-1830	843.6	3,246.0	8,492.4
1831-1835	815.2	2,849.4	6,617.0
1836-1840	1,020.6	3,739.2	10,860.8
1841-1845	980.2	4,762.8	17,370.2
1846-1850	1,459.2	8,199.8	25,048.8

Sources:

1807; VILLEFROSSE, *op. cit.*, p. 240.
1823-1825; KARSTEN (ed.), *Archiv für Bergbau*, op. cit., XIV, p. 123; XV, p. 405.
1826-1836; KARSTEN (ed.), *Archiv für Mineralogie*, op. cit., I, pp. 200-206; II, pp. 159-167; IV, pp. 284-288; V, pp. 314-320; VII, pp. 201-209; VIII, pp. 249-253; IX, pp. 623-626; X, pp. 3-26.
1837-1847; NEUMANN, *op. cit.*, pp. 111-113, 149-151, and 313-315.
1848-1850; VIEBAHN, *Statistik des Zollverein*, op. cit., II, pp. 446-485.

Notes:

* The 1807 zinc estimate has been adjusted to make it compatible with the later ones. This is due to the fact that the former represents calamine, and the latter spelter. In this adjustment, calamine has been assumed to contain, on average, 70 percent recoverable zinc.

V.

So far, it has been suggested that German non-ferrous metal production had grown slowly in the closing stages of the eighteenth century and then, under a combination of unusual wartime influences, reached a peak sometime in the period 1804-08. After 1814, and a return to 'normal' conditions, it is fairly certain that the fortunes of these industries waned. Output of copper and lead stagnated in the period 1823-35, while the impressive gains in zinc production were largely lost between 1826 and 1835 (table 4). It was only after the early 1840s that production began to grow healthily again, and at last surpass the wartime levels of output.

The reasons for the stagnation in the post-war period can be suggested as falling under five headings: first, physical destruction of plant and dislocation of production factors during wartime conditions; second, the possibility that the Germans lacked technological skills required after the withdrawal of the French; third, that there was a corresponding lack of venture capital in German hands; fourth, a lack of new reserves of mineral deposits which could be developed; and fifth, the dislocation of markets established during the war period, with a corresponding sluggishness in consumer demand for the products of these industries after 1814.

The physical destruction of plant and dislocation of factors of production before 1814 certainly left some legacy to the pattern of post-war industry, but it would seem that this legacy was a limited one. It has already been noted (above, p. 138) that a part of the Silesian zinc industry was disrupted during the closing stages of hostilities. However, this was one of the exceptional areas and, as Crouzet has argued,[66] « the Napoleonic Wars were not marked by large-scale physical destruction... such destruction as there was remained quite limited in space and time ». If a contrast be made with the destruction of Germany during the Thirty Years War (see p. 133 above, on the Mansfeld mine) it can be seen that as a whole north-west Europe escaped lightly from that aspect of warfare in the years 1803-14.

The possibilities of lack of technological skills, venture capital and new exploitable resources can be dealt with together, being closely related. Rondo Cameron has suggested that « the ores of zinc, lead, copper and silver abounded in Germany, especially in the Rhineland and Silesia. In the early nineteenth century some of these deposits were worked sporadically and on a small scale, but the Germany of that time lacked both the engineering skill and the venture capital to develop them fully... France, on the other hand... possessed both the technical proficiency and requisite capital, but lacked the necessary raw materials ».[67] Thus he implies a situation in which the Germans were unable to exploit the mineral deposits which were undoubtedly known to exist.

While it is probable that German mining and metallurgical entrepreneurs were facing a shortage of capital,[68] it is much less certain that they lacked the requisite technological skills. With a long tradition of mining and metallurgical activity stretching back to Agricola in the mid-

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[66] *Loc. cit.*, p. 567.

[67] *Some French contributions*, loc. cit., p. 284.

[68] CAMERON, *ibid.*, pp. 284-285 and 316-319 shows that in the period 1837-71, when French involvement in German non-ferrous metal production was greatest, it was particularly in the provision of investment capital that the French were prominent, e. g. he shows that the capitalisation of some of the larger German lead and zinc companies were made up of between 50 and 100 per cent French shareholdings.

sixteenth century (see footnote 8), even after the mixed fortunes of the non-ferrous metal industries in the seventeenth and eighteenth centuries, German skills in this field were still acknowledged as amongst the best in the world. Innumerable contemporary writers support this view. John Percy, the prominent English metallurgist, wrote in 1861:[69]

> The chief writers on metallurgy are the Germans, to whom we owe two of the most remarkable works on the subject, namely, the treatise of Agricola, in Latin... and the System of Metallurgy of Karsten,[70] in German, published in 1831. The monographs, contributions to periodicals, and compendious treatises relating to the science and practice of metallurgy which have been published in the German language are very numerous. We are, probably, indebted to the Germans, to a greater extent than is commonly supposed.

Another writer, the English mining engineer John Taylor, wrote in 1829 that in the art of mining « all other countries must acknowledge themselves more or less indebted to the Germans as their teacher... ».[71] In 1840, John Bowring, a British commercial and diplomatic emissary reported that the skills of the Germans in producing and manufacturing metals were in advance of those in his own country,[72] then the so-styled 'workshop of the world'. Overall it is certain that the Germans did possess a certain degree of technological competance and, contrary to the argument put forward by Cameron, this was by no means as responsible for the slow progress of non-ferrous metal production as was the lack of investment capital.

The final explanation advanced for the retardation of growth in these industries is that connected with market demand. In the period 1803-10 rising prices imply that there was an imbalance between supply and demand, and resulting in a market situation favourable to the then high-cost German producers. Similarly, after 1814, the falling trend of prices (table 5), caused largely by expanding world output overtaking the expansion of aggregate demand,[73] resulted in a fundamental set-back to producers in Germany. More specifically, non-ferrous metal production in the latter

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[69] *Metallurgy: copper, zinc, brass etc.* (John Murray: 1861), p. v.

[70] C. J. B. KARSTEN (1782-1853), editor of early German production records (see footnote 2), was a chemist and metallurgist, who did much practical work to foster the non-ferrous metal industries, and in 1817 was co-discoverer of the element cadmium; see « Brockhaus Enzyklopädie » (Wiesbaden, Brockhaus: 1970), IX, p. 793.

[71] *Records of Mining* (1829), p. i.

[72] « British Sessional Papers », House of Commons (1840), XXI, p. 381, *Report on the Prussian Commercial Union.*

[73] Pre-1850 statistics of consumption are to all intents and purposes unavailable. Average annual world output of metals rose, between the periods 1821-1825 and 1846-1850: copper, 77.3 thousand tonnes to 192.5; lead, 285.5 thousand tonnes to 680.5, and zinc, 33.3 thousand tonnes to 202.0; NEUMANN, *op. cit.*, pp. 114, 152 and 316.

country had geared itself to the French market during the war period. Normally, in peace time, France imported a large proportion of her non-ferrous metals from Britain, and the demand for German metals in the former country declined rapidly after 1815 as soon as British supplies were resumed. By this time, internally generated demand was probably not enough to support the levels of output reached between 1803 and 1810;

TABLE 5

NON-FERROUS METAL PRICES IN GERMANY, 1816-1850
(*marks/tonne*)

Annual average	Copper [a]	Lead [b]	Zinc [c]
1816-1820	2,000	461 [d]	302 [e]
1821-1825	1,850 [f]	474	600 [g]
1826-1830	1,820	465 [h]	315
1831-1835	1,880	318 [i]	230 [j]
1836-1840	1,900	405 [k]	289
1941-1845	1,800 [l]	389	411
1846-1850	1,720	341 [m]	271

Source: NEUMANN, *op. cit.*, copper, p. 118; lead, p. 153; zinc, p. 320.

Notes:

[a] Price at Mansfeld.
[b] Price at Tarnowitz.
[c] Price in Silesia.
[d] Minimum 448 marks in 1818.
[e] Minimum 210 marks in 1820.
[f] 1825 minimum, 1740 marks.
[g] 1822-1825 average.
[h] Maximum 1828, 498 marks.
[i] Minimum 1833, 264 marks.
[j] Minimum 1835, 150 marks.
[k] Maximum 1837, 454 marks.
[l] Minimum 1845, 1670 marks.
[m] Minimum 1849, 297 marks.

the Germany of 1815 had not yet developed a large broad-based non-ferrous metal consuming industrial sector. The effects of the post-war dislocation of markets has recently been described by one German economic historian,[74] « after the lifting of the Continental Blockade and the disappearance of wartime demand, a series of years which were on the whole very poor, put paid to many hothouse plants ».

With a lack of consumption figures it is impossible to measure the German domestic demand for non-ferrous metals between 1815 and 1850, but by looking at indirect evidence it may be feasible to indicate how and to what extent demand may have been increasing. Lead was consumed principally in pipes and sheets for construction purposes, and as an oxide in paint. Copper was consumed mainly as pipes, sheets and wire, in house

74 KNUT BORCHARDT, *The Industrial Revolution in Germany, 1700-1914*, « Fontana Economic History of Europe », IV, 1 (Collins: 1972), pp. 93-94.

construction and in boiler and machine making. Zinc was used as sheets in construction, after the 1840s in galvanised iron, and in conjunction with copper as brass, a prime component in a wide range of machine parts, industrial and household implements, and ornaments.[75] To a lesser extent than pre-1815, these metals were also used in the manufacture of munitions.

Data of house construction and the products of the mechanical engineering industries are very imperfect, but by considering such occasional representative statistics as are available it may be possible to explain consumption patterns for non-ferrous metals in this period. For example, the growth of railways could be taken as an indicator; in 1840 the total length of German railways was 469 kilometres, compared with 497 in France and 2390 in Britain.[76] By 1850, though, the figures were; Germany 5856 kilometres, France 2915 kilometres and Britain 9797 kilometres. Germany's relatively slow progress before 1840 was beginning to speed up. As this acceleration became prominent on a broad-based industrial front, in the 1840s and 50s, consumption of copper, lead, zinc and brass must have expanded faster, providing greater stimulus to domestic metal production. Increasing output did not cover demand, except in the case of zinc, as Von Walterhausen pointed out:[77] (in the period 1833-48) « copper, mined in the Mansfeld district, was still not sufficient for the quantity demanded. Lead came from Spain, tin from England. Zinc, from Silesia attained, before all other metals, the position of covering home demand and providing a surplus for export ». In such a situation, as growing national unity and industrialization grew hand-in-hand in the middle years of the nineteenth century, the necessary stimulus to German non-ferrous metal production was forged.

VI.

At the beginning of the nineteenth century the countries of western continental Europe were struggling first with the problems of war, and later with the problems of rapid economic and social change. These problems were intricately entangled. In this short study, some of the relationships between war, peace and growth in one sector of the German economy have been examined. A wide range of questions may be asked

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[75] On the uses of metals, see W. ALEXANDRE and A. STREET, *Metals in the Service of Man* (Harmondsworth, Penguin: 4th ed., 1962).

[76] Figures from B. R. MITCHELL, *Statistical Appendix, 1700-1914*, « Fontana Economic History of Europe », IV, 2 (Collins: 1972), p. 789.

[77] A. SARTORIUS VON WALTERHAUSEN, *Deutsche Wirtschaftsgeschichte, 1815-1914* (Jena, Fischer: 1920), p. 91.

which could extend study of the subject, and of the broader background. If the industrial revolution on the continent is held to have commenced in 1815,[78] what ingredients of the later industrialisation were being added in the period 1790 to 1815? In what ways did the Napoleonic Wars mark the start of an economic awakening in Germany, or an anticipation of future expansion?

In a sense, the passing achievements of the *Corps royal des mines de France* reflected only an indication of what the German economy might achieve under false laboratory conditions — equivalent levels of output only occured after a longer period of broad-based industrial evolution. On the other hand, Villefrosse and his colleagues did achieve something. As Joseph Schumpeter has pointed out,[79] during the war period, « in Germany... a lot of institutional deadwood... was eliminated practically everywhere in the territories that came directly or indirectly under French rule ». The beginnings of French involvement in the German non-ferrous metal industries had been securely laid and many new techniques introduced. These relationships came to fruition in the 1840s, 50s, and 60s, as adequately described by Rondo Cameron,[80] and were undoubtedly of great importance to the development of these industries. Knut Borchardt [81] has argued that the most important changes in the German mining industries were delayed until the second half of the nineteenth century. In terms of production levels this is a fairly accurate observation. However, when considering the introduction of capital and a market by the French during the war years, and in the 1840s, and the development of entrepreneurship and technology during the same period, this is an invalid view. If nothing else, the period of the Continental System gave a foretaste of the potential future development of the German non-ferrous metal industries, which forced its way to completion through the difficult years between 1815 and 1850.

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78 See W. O. HENDERSON, *The Industrialisation of Europe 1780-1914* (Thames and Hudson: 1969), p. 11; and J. H. CLAPHAM, *The Economic Development of France and Germany 1815-1914* (Cambridge: 4th ed., 1948), p. 1.

79 *Business Cycles* (McGraw-Hill: 1939), I, p. 257.

80 « France and Economic Development », *op. cit.*, and *Some French Contributions*, *loc. cit.*.

81 *Loc. cit.*, p. 130.

APPENDIX

ANNUAL FIGURES OF GERMAN NON-FERROUS METAL PRODUCTION, 1823-50

(Unamended data, sources as in table 4, p. 142)
The break in the series, 1847-48 is explained on pp. 142-143

(*tonnes*)

	Copper	Lead	Zinc
1823	931	1,166	7,800
1824	630	1,231	10,819
1825	772	1,328	12,686
1826	836	1,203	10,047
1827	749	1,375	11,428
1828	873	1,239	9,436
1829	835	853	6,822
1830	925	740	4,729
1831	810	829	5,719
1832	817	738	5,823
1833	787	588	6,969
1834	816	1,208	7,093
1835	846	1,386	9,481
1836	988	1,609	10,558
1837	1,000	1,399	11,085
1838	958	1,059	10,796
1839	1,025	960	11,133
1840	1,132	1,205	10,732
1841	979	1,076	10,278
1842	847	1,568	14,206
1843	1,042	1,234	18,546
1844	1,024	1,150	21,255
1845	991	2,910	22,561
1846	1,274	2,116	22,617
1847	1,331	1,743	22,751
...	...	...	...
1848	1,648	7,758	21,258
1849	1,361	8,999	27,972
1850	1,682	12,670	30,646