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*Preparing for the Next Blockade: Non-ferrous Metals and the Strategic Economic Policy of the Third Reich**

Scholars have long used developments and decisions in the field of Nazi economic policy to obtain an insight into Hitler's reasoning and intentions, especially with regard to the late 1930s and the coming of war.[1] This is because Hitler's statements during this period were often of a tactical and hence contradictory nature, which can therefore be used to support different scholarly interpretations.[2] Policies relating to strategically important non-ferrous metals are among those that have been used to this end.[3] These metals, such as copper and nickel, were indispensable for waging war because they were used in most of the commodities demanded by the Wehrmacht, including shells, armoured steel, and electrical equipment.[4] Yet, in the case of most metals, pre-war Germany was heavily dependent on imports, in particular (and in contrast to oil) from overseas.[5] Having experienced the Great War naval blockade, Hitler and other leading Nazis had to expect that these imports would be cut off in a war involving Britain as an antagonist.[6]

In spite of this expectation and the vital importance of non-ferrous metals for waging war, scholars agree that the Third Reich was badly prepared for a blockade and that the German economy would certainly

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1. See especially B.H. Klein, *Germany's Economic Preparations for War* (Cambridge, MA, 1959); A.S. Milward, *Die deutsche Kriegswirtschaft, 1939–1945* (Stuttgart, 1966); T.W. Mason, 'Innere Krise und Angriffskrieg, 1938/1939', in F. Forstmeier and H.-E. Volkmann, eds, *Wirtschaft und Rüstung am Vorabend des Zweiten Weltkriegs* (Düsseldorf, 1975), pp. 158–88; R.J. Overy, *War and Economy in the Third Reich* (Oxford, 1994); J.A. Tooze, *Wages of Destruction: The Making and Breaking of the Nazi Economy* (London, 2006).

2. See, for example, B.-J. Wendt, *Grossdeutschland: Aussenpolitik und Kriegsvorbereitung des Hitler-Regimes* (Munich, 1987), p. 164; B.-J. Wendt, 'Durch das "Strategische Fenster" in den zweiten Weltkrieg: Die Motive Hitlers', in U. Backes, E. Jesse and R. Zitelmann, eds, *Die Schatten der Vergangenheit: Impulse zur Historisierung des Nationalsozialismus* (Frankfurt am Main, 1990), pp. 344–74, at 347–8.

3. United States Strategic Bombing Survey (USSBS), *The Effects of Strategic Bombing on the German War Economy* (Washington, DC, 1945); Klein, *Germany's Economic Preparations*; Milward, *Die deutsche Kriegswirtschaft.*

4. See, for example, W. Treue, 'Hitlers Denkschrift zum Vierjahresplan', *Vierteljahrshefte zur Zeitgeschichte*, ii (1955), pp. 184–210.

5. USSBS, *Effects of Strategic Bombing*, p. 109, Table 62.

6. See, especially, G. Krumeich, ed., *Nationalsozialismus und Erster Weltkrieg* (Essen, 2010).

have run out of metals after only one or two years.[7] In the late 1930s the Western powers made similar coverage predictions (of about fifteen to eighteen months at most), and considered metals, besides fuel, to be *the* major weakness of the Nazi economy.[8] This strengthened the resolve of the British government to declare war on Germany and decisively influenced its 'long-war strategy', that is, to choke Germany economically before defeating it militarily.[9] Scholars also agree that little had been done before the war to reduce Germany's import dependency and that no significant consumption reductions by way of substitution and conservation had been implemented.[10] In addition, no rational war preparations, such as detailed mobilisation plans, seem to have been put in place in the field of non-ferrous mining.[11] Therefore, it seems at first glance that the German war-planners had not learned the lessons of the Great War and were not prepared for a longer conflict. Adam Tooze has recently claimed that nobody expected in 1939 that Germany could sustain a war as long as the Great War.[12] Germany's low raw material stocks made it unlikely. Accordingly, scholars dismiss contemporary statements by Hitler and other Nazi leaders that Germany was actually well prepared for a blockade as propaganda or as a 'theatre of illusion'.[13] Relying on these assumptions about the unpreparedness of the German economy, scholars conclude that Hitler was obliged to make an extremely risky gamble in the winter

7. See, for example, Klein, *Germany's Economic Preparations*, pp. 31–2, 57, 63; Milward, *Die deutsche Kriegswirtschaft*, pp. 18–19; H.-E. Volkmann, 'Die NS-Wirtschaft in Vorbereitung des Krieges', in W. Deist et al., *Das Deutsche Reich und der Zweite Weltkrieg*, I: *Ursachen und Voraussetzungen der deutschen Kriegspolitik* (Stuttgart, 1979), pp. 177–368, at 355–66; K.-H. Frieser, *The Blitzkrieg Legend: The 1940 Campaign in the West* (Annapolis, MD, 2005), p. 20.

8. USSBS, *Effects of Strategic Bombing*, p. 111; F.H. Hinsley, *British Intelligence in the Second World War*, I (London, 1979), p. 65; W.N. Medlicott, *The Economic Blockade*, I (London, 1952), p. 27; P. Kennedy, 'British "Net Assessment" and the Coming of the Second World War', in W. Murray, ed., *Calculations: Net Assessment and the Coming of World War II* (New York, 1992), pp. 19–59, at 34. For France, see P. Jackson, *France and the Nazi Menace: Intelligence and Policy Making, 1933–1939* (Oxford, 2000), pp. 358, 382. The French expected that Germany would only be able to resist for a few months in the case of a blockade: R.J. Young, 'French Military Intelligence and Nazi Germany, 1938–1939', in E.R. May, ed., *Knowing One's Enemies: Intelligence Assessment before the Two World Wars* (Princeton, NJ, 1984), pp. 271–301, at 295.

9. Medlicott, *Economic Blockade*, pp. 25–32; Overy, *War and Economy*, pp. 209–10.

10. B. Müller-Hillebrand, *Das Heer, 1933–1945: Entwicklung des organisatorischen Aufbaues*, II: *Die Blitzfeldzüge, 1939–41: Das Heer im Kriege bis zum Begin des Feldzuges gegen die Sowjetunion im Juni 1941* (Frankfurt am Main, 1956), p. 27; A.E. Bagel-Bohlan, *Hitlers industrielle Kriegsvorbereitungen, 1936–1939* (Univ. Bonn diss., 1973), pp. 7–11, 105–6, 218–19; J.-J. Jäger, *Die wirtschaftliche Abhängigkeit des Dritten Reichs vom Ausland dargestellt am Beispiel der Stahlindustrie* (Berlin, 1969), pp. 83–7, 89–94, 100–103; R. Banken, 'Die wirtschaftspolitische Achillesferse des "Dritten Reiches": Das Reichswirtschaftsministerium und die NS-Außenwirtschaftspolitik, 1933–1939', in A. Ritschl, ed., *Das Reichswirtschaftsministerium in der NS-Zeit: Wirtschaftsordnung und Verbrechenskomplex* (Munich, 2016), pp. 91–226, at 205.

11. Klein, *Germany's Economic Preparations*, pp. 37–8; J.A. Tooze, *Statistics and the German State, 1900–1945: The Making of Modern Economic Knowledge* (Cambridge, 2001), p. 231.

12. Tooze, *Wages of Destruction*, p. 335.

13. Ibid., p. 321; R.-D. Müller, 'Die Mobilisierung der Deutschen Wirtschaft für Hitlers Kriegsführung', in B. Kroener, R.-D. Müller and H. Umbreit, *Das Deutsche Reich und der Zweite Weltkrieg*, V: *Organisation und Mobilisierung des deutschen Machtbereichs*, pt. i: *Kriegsverwaltung, Wirtschaft und personelle Ressourcen, 1939–1941* (Stuttgart, 1988), pp. 349–692, at 359.

of 1939/40, when he ordered the use of the raw material stocks for an attack against the Western powers.[14] The fact that Germany, in contrast to the Allied powers' expectations, failed to run out of metals after one or two years, and that it did not lose the war because of a lack of metals, is explained by contingencies and non-predictable events—especially Germany's unexpected victories, which granted access to occupied Europe and its resources, and the 'ingenuity' of German engineers in conserving and substituting raw materials, especially once Albert Speer had become Armament Minister in 1942.[15] This article reconsiders the validity of all these statements by testing them against the availability of new economic and statistical evidence in the vitally important field of metals.

Assumptions about an ill-prepared Germany have long gone unquestioned because of their close fit with dominant scholarly paradigms. Even though historians disagree over how strong the German economy was at the end of the 1930s,[16] they agree that Germany was not ready for a 'long war' in 1939.[17] This was because Hitler planned to carry out only short wars (the 'Blitzkrieg hypothesis'), or because the envisaged major European war came prematurely.[18] The latter opinion is expressed by proponents of a second important interpretation (the 'Inefficiency hypothesis'), who explain the poor armament output during the first years of the war not by Hitler's lack of willingness fully to mobilise the German economy, but by the growing inefficiency and confusion of the military economy. This is said to have been caused by a number of structural and institutional factors, including a lack of central administrative control and rival bureaucracies involved in constant power struggles, a lack of incentives for firms to produce more efficiently, and the untimely outbreak of the war.[19] As a consequence, the use of those resources that were mobilised, such as raw materials, was ineffective, and substitution and conservation of scarce metals rather limited compared to later years. These inefficiencies, argue adherents of this hypothesis, only began to be overcome from mid-1941 onwards, especially once Albert Speer had been appointed armament minister in early 1942. In general, scholars frequently doubt whether even pre-war economic policies were successful, in part because the

14. Tooze, *Wages of Destruction*, pp. 336–8.

15. See, especially, Klein, *Germany's Economic Preparations*, pp. 113–14, 121, 216; Milward, *Die deutsche Kriegswirtschaft*, pp. 46–7; Overy, *War and Economy*, pp. 369–70.

16. On this disagreement, see, for example, Overy, *War and Economy*, pp. 202–32.

17. See, for example, ibid., p. 198; Müller-Hillebrand, *Das Heer*, p. 25; Tooze, *Wages of Destruction*, p. 315.

18. For the first view, see especially Milward, *Die deutsche Kriegswirtschaft;* for the second, Overy, *War and Economy.*

19. Overy, *War and Economy*, esp. pp. 29–30, 233–56, 347, 353–70. For most of these points, see also Müller, 'Die Mobilisierung der Deutschen Wirtschaft', esp. pp. 364–9, 432, 441–2, 455, 461, 639, 660, 672, 686.

problems of administrative struggles (polycratic chaos)[20] and a lack of centralisation can also be observed prior to the war.[21] The autarky measures of the Four-Year Plan are often regarded as a failure,[22] and the German economic administration, especially with regard to raw materials, as incompetent.[23]

Yet more recent studies challenge these long-standing paradigms and position the Nazi economy within an altogether different conceptual framework. Whereas previous interpretations sought to explain German defeat, and thus focused on German shortcomings in war planning and mobilisation, scholars have now begun to turn this question on its head. Rather than asking why the German war economy ultimately failed, they are exploring how it enabled Germany to hold out for so long against a far superior coalition.[24] Recent studies on science policy,[25] investment policy[26] and armament production[27] in the Third Reich have collectively questioned long-held assumptions about the incompetence of German economic administration up to 1942, about the importance of the rationalisation drive in the second half of the war, and whether German authorities prepared only for short wars. In addition, recent scholarship on the administrative workings of the Third Reich has argued that previous research has tended to overestimate the negative impact of inter-ministerial turf battles on administrative efficiency.[28] All these studies suggest that the German

20. On polycratic chaos in the historiography of the Third Reich, see I. Kershaw, *The Nazi Dictatorship: Problems and Perspectives of Interpretation* (3rd edn, London, 1996), pp. 63–7.

21. See, for example, Müller, 'Die Mobilisierung der Deutschen Wirtschaft', p. 356.

22. See, for example, R. Evans, *The Third Reich in Powe*r (London, 2005), pp. 361–2.

23. Jäger, *Die wirtschaftliche Abhängigkeit*, pp. 83–90, 94, 100–105; Bagel-Bohlan, *Hitlers industrielle Kriegsvorbereitungen*, pp. 7–11, 105–6, 218–19.

24. K.C. Priemel, 'Lernversagen', in Krumeich, ed., *Nationalsozialismus*, pp. 299–322, at 321; S. Flachowsky, R. Hachtmann and F. Schmaltz, 'Wissenschaftspolitik, Forschungspraxis und Ressourcenmobilisierung im NS-Herrschaftssystem', in S. Flachowsky, R. Hachtmann and F. Schmaltz, eds, *Ressourcenmobilisierung: Wissenschaftspolitik und Forschungspraxis im NS-Herrschaftssystem* (Göttingen, 2016), pp. 7–32, at 17.

25. See, for example, H. Maier, *Forschung als Waffe: Rüstungsforschung in der Kaiser-Wilhelm-Gesellschaft und das Kaiser-Wilhelm-Institut für Metallforschung 1900 bis 1945/48* (Göttingen, 2007).

26. J. Scherner, *Die Logik der Industriepolitik im Dritten Reich: Die Investitionen in die Autarkie- und Rüstungsindustrie und ihre staatliche Förderung* (Stuttgart, 2008); J. Scherner, 'Nazi Germany's Preparation for War: Evidence from Revised Industrial Investment Series', *European Review of Economic History*, xiv (2010), pp. 433–68; J. Scherner, '"Armament in the Depth" or "Armament in the Breadth"? German Investment Pattern and Rearmament during the Nazi Period', *Economic History Review*, lxvi (2013), pp. 497–517.

27. Tooze, *Wages of Destruction*, pp. 552–89; L. Budraß, J. Scherner and J. Streb, 'Fixed-price Contracts, Learning and Outsourcing: Explaining the Continuous Growth of Output and Labour Productivity in the German Aircraft Industry during World War II', *Economic History Review*, lxiii (2010), pp. 107–36; J. Scherner and J. Streb, 'The Mirage of the German Armament Miracle in World War II', in J. Eloranta, E. Golson, A. Markevich and N. Wolf, eds, *An Economic History of Warfare and State Formation* (Tokyo, 2016), pp. 243–58.

28. See, especially, R. Hachtmann, 'Elastisch, dynamisch und von katastrophaler Effizienz—zur Struktur der Neuen Staatlichkeit des Nationalsozialismus', in S. Reichardt and W. Seibel, eds, *Der prekäre Staat: Herrschen und Verwalten im Nationalsozialismus* (Frankfurt am Main, 2011), pp. 29–74.

capacity for economic mobilisation was considerably greater than has long been assumed and that economic policy was far more continuous than was earlier believed.

Such findings demand a re-examination of Nazi Germany's preparations to become 'blockade safe'. This is especially true for non-ferrous metals. Despite the fact that German metal policy has been taken to epitomise the allegedly failed economic war preparations of the Nazi regime, metals are not only far less well researched than other autarky industries during the Third Reich, but existing studies rely on a very limited source basis and sometimes contradictory quantitative data.[29] This article, based primarily on previously unused source material from several public and company archives, re-evaluates German metal policy with a special focus on four vitally important metals: copper, tin, tungsten and nickel. With regard to these metals, Germany depended before the war nearly exclusively or primarily on supply from overseas.[30] By examining these metals, the article makes three major contributions. First, it provides a comprehensive account of one main but neglected focus of the Four-Year Plan, that is, metals, and analyses and quantifies the war preparations in this field as well as their implementation after 1939. Secondly, it addresses a long-standing research lacuna[31] by tracing how the experiences of the Great War shaped preparations for the next war. It shows that the German authorities had begun in the 1930s to put in motion programmes, based on the lessons learned from the Great War, that would allow them to massively cut consumption and increase supplies in case of war. Finally, the article shows that because of these measures, which were partly disguised through the use of disinformation, Germany was far better prepared in the vitally important field of metals than has long been believed. More broadly, the article challenges established understandings of German war preparedness, and argues that the Nazis may have believed in 1939 that they were sufficiently prepared, when it came to the field of non-ferrous metals, for a major, long-duration European war. The extent of Hitler's gamble in 1939, at least regarding these vitally important raw materials, was thus significantly smaller than scholars have believed. Germany lost the war not because of a lack of preparation, certainly not in the field of metals, but because of the strategic decision to start

29. Jäger, *Die wirtschaftliche Abhängigkeit*; D. Petzina, *Autarkiepolitik im Dritten Reich: Der nationalsozialistische Vierjahresplan* (Stuttgart, 1968); Bagel-Bohlan, *Hitlers industrielle Kriegsvorbereitungen*, p. 11. Note that our knowledge about Nazi Germany's metal policy contrasts starkly with a previously ignored assessment made by the contemporary non-ferrous metal expert and anti-Nazi Ferdinand Friedensburg, who praises in his memoirs this aspect of the war preparations: F. Friedensburg, *Lebenserinnerungen* (Frankfurt am Main, 1969), p. 277.

30. Thus, metals such as zinc or vanadium, where Germany's import dependency was quite low or the country could even become self-sufficient, are less in focus.

31. Müller, 'Die Mobilisierung der Deutschen Wirtschaft', p. 351; Priemel, 'Lernversagen', p. 300. A first attempt was recently made in J. Scherner, 'Lernen und Lernversagen: Die "Metallmobilisierung" im Deutschen Reich, 1939 bis 1945', *Vierteljahrshefte für Zeitgeschichte*, lxvi (2018), pp. 233–66.

a war which was bound to draw in an ever more superior coalition of enemies the longer it lasted.

I

When the German authorities started to prepare for the next conflict, the Great War had been over for only fifteen years. As a consequence, it was not only very present in the minds of the leading Nazis, but the administrative and ministerial bureaucracy tasked with this preparation often consisted of people who had already served in Imperial Germany's war administration.[32] They were acutely aware that the problems Germany had faced with regard to metals in 1914 remained the same in the 1930s: on the one hand, a huge overseas import dependency, and, on the other hand, the fact that these metals were essential for waging war. Thus, it would have been surprising if the experiences of the Great War were ignored when preparing for the next war. In learning the lessons of the Great War, those in charge of war preparation could draw not only on their personal experiences, but also on relevant publications by former members of Imperial Germany's war administration.[33] Moreover, they could consult several specific studies, full of details and statistics, originally commissioned by the Imperial government in order to learn from the Great War. While the publication of these studies had been suppressed for several reasons during the 1920s, a few classified copies were circulated among German governmental agencies.[34]

This body of restricted material on the Great War's lessons for the war economy grew remarkably after the Nazis took power. In the field of metals alone, and in the main on behalf of different agencies of the Nazi government, the military history department of the German National Archive (Reichsarchiv) and its successor institutions wrote several studies between 1933 and 1939, often occupying more than a hundred pages, and sometimes several volumes (see Table 1). These studies covered all important aspects of Imperial Germany's war metals policy. Based on rich qualitative and quantitative archival material as well as on interviews with former key personnel, they facilitated the transfer of knowledge from

32. See, for example, P. Fröhlich, *'Der unterirdische Kampf': Das Wehrwirtschafts- und Rüstungsamt, 1924–1943* (Paderborn, 2018), p. 228.

33. See, for example, J. Koeth, 'Rohstoffbewirtschaftung', in G. Anschütz et al., eds, *Handbuch der Politik* (3rd edn, 6 vols, Berlin, 1920–26), ii, pp. 224–33; R. Tröger, 'Technik in der Metallwirtschaft', in M. Schwarte, *Die Technik im Weltkriege* (Berlin, 1920), pp. 514–25; O. Goebel, *Deutsche Rohstoffwirtschaft im Weltkrieg einschließlich des Hindenburgprogramms* (Stuttgart, 1930); K. Wiedenfeld, *Die Organisation der Kriegsrohstoffbewirtschaftung im Weltkriege* (Hamburg, 1936).

34. R. Haus, 'Die Ergebnisse der Wissenschaftlichen Kommission beim Preußischen Kriegsministerium im Spannungsfeld divergenter Interessen', in M. Boldorf and R. Haus, eds, *Die Deutsche Kriegswirtschaft im Bereich der Heeresverwaltung, 1914–1918: Drei Studien der Wissenschaftlichen Kommission des Preußischen Kriegsministeriums und ein Kommentarband*, IV: *Die Ökonomie des Ersten Weltkriegs im Lichte der zeitgenössischen Kritik* (Berlin, 2016), pp. 13–138, at 121; Koblenz, Bundesarchiv [hereafter BArch], R 1501/108980, Reichswirtschaftsminister to Reichsminister des Inneren, 7 Apr. 1923, fo. 242.

Table 1. Learning from the Great War: classified studies related to non-ferrous metals during the inter-war period.

Title of survey	Content	Volumes; pages	Year finished
Technological lessons from the Great War	Substitution; conservation	2 vols; 1,087 pp.	1922
'Metal policy during the Great war'	Rationing, evolution, organisation, problems; metal mobilisation, substitution, exploration of ores, smelters, refineries, trade, R&D; statistics	> 243 pp.	Early 1920s
'Kriegsmetall AG'	Foundation, organisation	1 vol.; 62 pp.	1931
'Substitution'	Substitution of scarce metals in armament production	3 vols	1933
'Metal mobilisation'	Evolution, data, organisation, problems	*c.*130 pp.	1934
'Substitution'	Substitution of scarce metals in armament production	6 vols	1935
'Scrap'	Investment in recycling smelters, recycling R&D	1 vol.	1935
'Foreign trade'	Evolution, problems	1 vol.	1936
'Foreign trade'	Data; commodities, countries	7 vols	1936/7
'Metal policy, 1914–16'	Rationing, evolution, organisation, problems; metal mobilisation, substitution, exploration of ores, refineries, trade; statistics	1 vol.	1937

Sources: Verein Deutscher Ingenieure (VDI), *Technische Kriegserfahrungen für die Friedenswirtschaft, im Rahmen der volkwirtschaftlichen Untersuchungen der ehemaligen Mitglieder der Wissenschaftlichen Kommission des Preußischen Kriegsministeriums* (Berlin, 1923) (unpub.); BArch, RH 61/860, Kriegsgeschichtliche Forschungsabteilung des Heeres, 'Rohstoff-Referat, Im Panzerschrank aufzubewahrende Arbeiten', 25 June 1942; Hildebrand an von Kalm, 'Vorhandene Arbeiten und Unterlagen', 13 Apr. 1943; Inventare des Reichsarchivs, 'Im Auftrag der 7. Abteilung (bzw. ihrer Vorgängerinnen) angefertigte Denkschriften'; BArch, RH 60/9, 'Zusammenstellung der Kriegserfahrungen bis 1.2.1938 bei der 7. Abteilung des Generalstabes des Heeres erschienen Einzelarbeiten'; BArch, RH 61/843, Auszug aus Lindig, 'Die staatliche Bewirtschaftung der Nichteisenmetalle im Kriege', fos 102–43.

the Great War to the planners of the Second World War.[35] These studies were heavily classified and even stored in strong-rooms.[36] Nonetheless, they were regularly used by the German administration during the 1930s

35. For interviews, see, for instance, BArch, RH 61/679, note, 7 Mar. 1938.

36. BArch, RH 61/860, 'Kriegsgeschichtliche Forschungsanstalt des Heeres, Rohstoff-Referat, Im Panzerschrank aufzubewahrende Arbeiten', 25 June 1940. Not all of these studies survived the Second World War.

and 1940s.[37] The significance of these surveys is reflected in the fact that they were condensed into a sort of encyclopaedia on the behalf of the Heereswaffenamt (HWA), the agency responsible for the technical development of armaments and the organisation of the production of munitions.[38] This encyclopaedia, including an index and references to the surveys, served as a quick reader for the employees of the HWA and provided precise suggestions for the next war. The classified book series from the early 1920s whose publication was suppressed also had a significant impact on Germany's war preparation. In 1937 the German war minister Werner von Blomberg wrote, in a congratulatory letter for the 80th birthday of the series' editor, Max Sering, that 'today's Wehrmacht was built up on the basis of your work in the past, and because of this, [your work] constitutes one of the foundations of the present military science studies'.[39] In 1940, one of the authors of this series even became head of the department for steel and metals in the newly founded ministry for munitions because of his expertise.[40] Given this knowledge transfer from the experiences of the Great War, there can be no doubt that the German war planners had precise knowledge of how to overcome the effects of a future sea blockade.

II

A specific metal policy of the Third Reich can be traced as early as 1934. In the spring of this year, the Reichsbank's foreign currency reserves diminished dramatically, largely because the decline of exports that had started in 1932 continued, while imports of raw materials and foodstuffs rose on account of the needs of rearmament and growing civilian demand caused by the upswing of the economy.[41] Hjalmar Schacht, president of the Reichsbank since 1933 and Minister for Economic Affairs since August 1934, implemented his 'New Plan' (*Neuer Plan*) in order to improve the German balance of payments in the long run. Scarce foreign currency was to be used primarily for essential imports: foodstuffs, raw materials and semi-finished goods for rearmament and the export industry. Around the same time, the use of some metals for certain purposes was prohibited and their substitution ordered.[42] For example, newly installed power lines

37. See, for example, BArch, RH 60/9, 'Zusammenstellung der Kriegserfahrungen bis 1.2.1938 bei der 7. Abteilung des Generalstabes des Heeres erschienen Einzelarbeiten', foreword; Scherner, 'Lernen und Lernversagen', p. 238.

38. BArch, RH 60/9, 'Zusammenstellung der Kriegserfahrungen bis 1.2.1938 bei der 7. Abteilung des Generalstabes des Heeres erschienen Einzelarbeiten'.

39. R. Haus, '"Die deutsche Eisenwirtschaft während des Krieges" von Alfred Stellwaag: Ein Standardwerk zur Eisen- und Stahlindustrie des Ersten Weltkriegs', in Boldorf and Haus, eds, *Die Deutsche Kriegswirtschaft*, IV, pp. 193–221, at 211.

40. Ibid., pp. 193–5, 211.

41. For the following, see M. Ebi, *Export um jeden Preis: Die deutsche Exportförderung von 1932–1938* (Stuttgart, 2004), pp. 32–92, 117–91; Tooze, *Wages of Destruction*, pp. 71–96.

42. See, for example, F.L. Neher, *Kupfer, Zinn, Aluminium* (Leipzig, 1940), p. 338; Maier, *Forschung als Waffe*, pp. 367–72.

were to be produced with aluminium instead of copper.[43] The institution in charge of the substitution programmes, as well as monitoring the prohibitions, was the newly founded Überwachungstelle für Metalle (Monitoring Agency for Metals).[44]

This policy was strengthened in the following years, especially after the Four-Year Plan was implemented in the autumn of 1936. In his famous secret memorandum about the Four-Year Plan, Hitler sketched the policies necessary to prepare Germany for a war.[45] In this context he emphasised the role that substitutes, such as light metals, and substitution research should play in further reducing the consumption of non-ferrous metals. This was without doubt a lesson that German war planners had learned from the Great War, when substitution and conservation measures in particular had allowed Imperial Germany to continue the war up to 1918.[46] As early as 1920, Richard Tröger, the wartime head of the metal section of Imperial Germany's raw material office, had predicted that in the future technological advances would enable a high level of self-sufficiency in the field of metals.[47] A second lesson of the Great War was that there would be a time-lag of some years between the start of substitution research and development (R&D) and the implementation of new measures.[48] Consequently, contemporary German authors urged, similarly to Hitler, that substitution should be prepared in advance of the next war.[49] The Four-Year Plan authority and other German agencies such as the HWA and the Air Force ministry tried to implement Hitler's demand through various measures. For example, they massively increased the funding of substitution R&D, established new research institutes and expanded existing ones, arranged exhibitions to increase acceptance of the use of substitutes, and fostered the exchange of substitution know-how among companies.[50]

43. H. Troeger, ed., *Die Anordnungen der Überwachungsstellen für die Metallindustrie und Vorschriften zur industriellen Rohstoffbewirtschaftung* (Frankfurt am Main, 1935), pp. 38–9.

44. Neher, *Kupfer, Zinn, Aluminium*, p. 338.

45. Treue, 'Hitlers Denkschrift zum Vierjahresplan', pp. 207–9.

46. See, especially, Tröger, 'Technik in der Metallwirtschaft', p. 524; L. Wurtzbacher, 'Die Versorgung des Heeres mit Waffen und Munition', in M. Schwarte, ed., *Der große Krieg, 1914–18*, I: *Die für den Kampf unmittelbar arbeitenden Organisationen* (Leipzig, 1921), pp. 69–146, at 120; Verein Deutscher Ingenieure (VDI), *Technische Kriegserfahrungen für die Friedenswirtschaft, im Rahmen der volkwirtschaftlichen Untersuchungen der ehemaligen Mitglieder der Wissenschaftlichen Kommission des Preußischen Kriegsministeriums* (Berlin, 1923) (unpub.), p. 22.

47. Tröger, 'Technik in der Metallwirtschaft', p. 524.

48. VDI, *Kriegserfahrungen*, pp. 33–6.

49. See, for example, ibid., p. 3; H. Garcke, 'Unterlassungssünden in der militärischen Rüstung Deutschlands vor dem Kriege', in W. Jost and F. Felger, eds, *Was wir vom Weltkrieg nicht wissen* (Leipzig, 1936), pp. 72–88, at 85–6; H. Hunke, 'Wehr und Wirtschaft im großen Kriege', ibid., pp. 357–65, at 364.

50. BArch, R 13 XII/303, Der Reichsbeauftragte für unedle Metalle to Fachgruppe chemische Herstellung von Fasern, 12 Jan. 1937; C. Krauch, 'Forschung und Entwicklung: Aufgaben und Arbeiten des Amtes für deutsche Roh- und Werkstoffe', in *Der Vierjahresplan. Zeitschrift für nationalsozialistische Wirtschaftspolitik*, i, no. 5 (1937), pp. 261–3; Maier, *Forschung als Waffe*, pp. 427–8, 565–6, 687, 967–9; H. Maier, 'Autarkie- und Rüstungsforschung und die Technischen Hochschulen im "Dritten Reich"', in W.A. Herrmann and W. Nerdinger, eds, *Die Technische Hochschule München im Nationalsozialismus* (Munich, 2018), pp. 34–49.

R&D was carried out by both public research institutions and private companies. Sometimes the R&D fell entirely to firms, sometimes they were involved only in the testing and development phase.[51] Networks of research institutes, universities and companies, which had been established shortly after Hitler came to power, very often co-operated to meet the substitution demands of state agencies.[52] Moreover, the state subsidised the build-up of production sites of raw materials which could serve as substitutes, such as zinc, aluminium and vanadium.[53] The rationing of non-ferrous metals, implemented in early 1937, was an additional incentive to use substitutes.[54]

The effects of this pre-war metal substitution and conservation policy were quite impressive. In 1936/7 the use of substitutes, such as light metals or plastics, and metal-conserving constructive modifications had already reduced the domestic consumption of copper by 31 per cent. Reductions in the consumption of tin, nickel and lead, were substantial, too, as is shown in Table 2. This consumption reduction, however, did not only negatively affect the quality of products in some cases, but also often entailed higher unit costs for German producers, at least in the short run, even if some cases of cost reductions were also reported.[55]

This substitution process continued up to the outbreak of war: for instance, the ratio of copper and aluminium consumption in the cable industry, normally one of the major copper consumers, which had already massively decreased between 1933 and 1936, continued to

51. Examples include the cement producer Dyckerhoff, which undertook R&D in the case of a new technology to produce alumina out of German raw materials on behalf of the Four Year Plan authority; the steel and armament producer Krupp, which worked on behalf of Wehrmacht agencies on substitutes to be used in shells; and the machinery producer Zahnradfabrik Friedrichshafen, which tested on behalf of the Reichsstelle für Stahl and Eisen (Reich Agency for Steel and Iron) new steel alloys as a possible substitute for molybdenum. For these examples, see (in order): J. Scherner, 'Staatliche Förderung, Industrieforschung und Verfahrensentwicklung: Die Tonerdeproduktion aus deutschen Rohstoffen im Dritten Reich', in Flachowsky, Hachtmann and Schmaltz, eds, *Ressourcenmobilisierung*, pp. 383–422; Essen, Historisches Archiv Krupp [hereafter HA Krupp], WA 40/259, fo. 79, 'Niederschrift über die Besprechung in Berlin', 23 Sept. 1936; fo. 93, 'Erklärung unter Eid Fritz Licke (NIK-12534)'. BArch, R 13 III/1621, 'Erfahrungen mit Einsatzstählen EC-80, EC-100 und ECMO-200 (Bericht über die Ergebnisse von Betriebs-, Laboratoriums- und Fahrversuchen der Zahnradfabrik Friedrichshafen; Druck)', 24 Oct. 1940.

52. Maier, 'Autarkie- und Rüstungsforschung'; Maier, 'Ideologie', pp. 368–85; Maier, *Forschung als Waffe*, pp. 594–5, 607–8, 974–5, 1110. On the role of the Four Year Plan authority, see also S. Flachowsky, 'Das Reichsamt für Wirtschaftsausbau als Forschungsbehörde im NS-System: Überlegungen zur neuen Staatlichkeit des Nationalsozialismus', *Technikgeschichte*, lxxxii (2015), pp. 185–224.

53. See, for example, BArch, R 2/15355, fo. 281, Der Reichs- und Preußische Wirtschaftsminister to Mansfelder Kupferschieferbau Aktiengesellschaft, 25 Sept. 1937; BArch, R 2/15356, fo. 130, 'Bau einer Vanadiumanlage', 15 Apr. 1938.

54. On rationing of of non-ferrous metals, see BArch, RW 19/84, fo. 83, Wehrwirtschaftsstab, 'Stand der wirtschaftlichen Lage', 1 May 1937; BArch, RL 3/573, LC 2II, note, 1 June 1938.

55. For unit cost increases, see, for instance, M. Geyer, 'Rüstungsbeschleunigung und Inflation: Zur Inflationsdenkschrift des Oberkommandos der Wehrmacht vom November 1938', *Militärgeschichtliche Mitteilungen*, xxx, no. 2 (1981), pp. 121–86, at 182. For cost reductions, see, for example, Neher, *Kupfer, Zinn, Aluminium*, pp. 363–4.

Table 2. Consumption reduction in 1936/7 in the case of non-ferrous metals.

	Metals			
	Copper	**Tin**	**Nickel**	**Lead**
(1): By constructive modifications (in 1000 metric t)	31.5	0.4	0.5	3.5
(2): By light metals (in 1000 metric t)	26.3	1.2	1.9	14
(3): By plastics (in 1000 metric t)	31.5	1.6	0.0	14
(4): By wood (in 1000 metric t)	5.1	0.2	0.0	0.0
(5): By glass and ceramics (in 1000 metric t)	10.5	0.6	0.3	3.5
(6): Total consumption reduction (1)–(5) (in 1000 metric t)	105	4	2.7	35
(7): (6) related to counterfactual domestic consumption (in %)	31%	26%	22%	14%

Sources and notes: For rows (1)–(6), see BArch, R 3112/58, fo. 16, 'Schema der Bedarfsminderung durch Austausch von Schwermetallen, Nov. 1937 (Amt für Deutsche Roh- und Werkstoffe)'; BArch, R 3112/165, fos 15, 34, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan. Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'. Given that both sources are not unambiguous as to whether the data refers to 1936 or 1937, domestic consumption is calculated as the average of the consumption of both years (which was quite similar). For domestic consumption, see BArch, 3112/27, fos 25–6, 'Verbrauch'. Note that the absolute substitution figures in metric tons, as given by an internal survey of the Four-Year Plan authority, are in row (7) related to domestic consumption, and not to total German consumption figures, because substitutes were normally not used when producing commodities for foreign markets: BArch R 3112/165, fos 34–5, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan. Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'. On Löb, see U. Schlie, ed., *Albert Speer: Die Kransberg-Protokolle 1945* (Munich, 2003), p. 330.

drop in the following years.[56] The substitution of tin, too, developed in a similar way during these years.[57] Between 1935/6 and 1938/9, the content of nickel in construction steel was reduced by 80 per cent, that of chrome and of molybdenum by 31 per cent and 34 per cent respectively.[58] In other cases scarce alloys such as tungsten were partially substituted by vanadium, in which Germany was self-sufficient. The monthly vanadium consumption, which had already increased by more than 50 per cent between 1934 and 1936, was in 1938 almost three

56. For 1933, 1937 and 1938, see BArch, R 3102/6124, Elt4; for 1936, BArch, R 3102/3546, 'Produktionserhebung für das Kalenderjahr 1936 über die Herstellung von Kabeln und isolieren Leitungen'.

57. In 1939, the total amount of tin conserved was 6,800 tons, which constituted about 50 per cent of Germany's annual pre-war consumption: BArch, R 3112/13, note, 19 Dec. 1939.

58. E. Houdremont, 'Der Edelstahl in der Entwicklung', *Der Vierjahresplan. Zeitschrift für nationalsozialistische Wirtschaftspolitik*, iv, no. 15 (1940), pp. 649–52.

times higher than in 1936.[59] In other words, pre-war substitution was spectacular. Indeed, substitution was a field where the Four-Year Plan's original quantitative goals and expectations were widely exceeded.[60] This success, however, was carefully concealed. From 1935 onwards, the Nazi regime hid the extent of the effects of substitution (and the extent of stockpiling), as the German Statistical Office stopped publishing metal consumption data.[61] Thus, the British Industrial Intelligence Centre (IIC), an intelligence hub that was established to investigate German industrial war preparation,[62] had to rely on the expert opinion of British producers, which probably explains why it massively overestimated German consumption at the end of the 1930s; by 67 per cent in the case of tin, by 33 per cent in the case of copper, and by 26 per cent in the case of nickel.[63]

Yet, on the eve of the war, the Nazi regime was fully aware that there was still a significant untapped potential for further conservation of non-ferrous metals. In spite of a massive output increase of substitution material, the demand for *Ersatz*, such as aluminium, could not be totally met during the late 1930s.[64] Moreover, a major conservation potential existed in armaments production. Even though some substitution programmes had been realised already, and even though massive and successful R&D efforts had been carried out, most of the latter had yet to be implemented in the production process. This was especially the case with regard to copper-intensive ammunition production, which made up between a half

59. For consumption data, see Jäger, *Die wirtschaftliche Abhängigkeit*, p. 164; USSBS, *Effects of Strategic Bombing*, Appendix, p. 264, Table 83.

60. In the case of tin, the effect of substitution expected in 1936 would cover 2,400 tons: BArch, R 3112/18, fo. 71, 'Rohstoff- und Devisenstab', Sept. 1936; fo. 80, 'Rohstoff- und Devisenstab', 13 Aug. 1936.

61. Generally on the concealment of information about raw material, see Hinsley, *British Intelligence*, p. 60. On Nazi publication policy with regard to sensitive data, see Tooze, *Statistics*, p. 184.

62. On the IIC, see especially Hinsley, *British Intelligence*; W.K. Wark, *The Ultimate Enemy: British Intelligence and Nazi Germany* (London, 1985), esp. pp. 155–87; G. Bennett, *Churchill's Man of Mystery: Desmond Morton and The World of Intelligence* (London, 2007), esp. pp. 135–200; R.J. Young, 'Spokesmen for Economic Warfare: The Industrial Intelligence Centre in the 1930s', *European Studies Review*, vi (1976), pp. 473–89.

63. For the IIC's estimates, see Kew, The National Archives, T 160/846, Department of Overseas Trade (I.I.C.), ICF/284, 'Germany: Supplies of Foodstuffs and Raw Materials in War', Appendix I, 1 June 1939. The figures for German copper and tin consumption in 1939 before the outbreak of the war are calculated on the basis of the information given by BArch, R 3/1868, 'Entwicklung der deutschen Metallversorgung seit Kriegsbeginn und Vorschau bis zum Jahre 1943, Reichswirtschaftsministerium—Metallreferat, Jul. 1943', and College Park, MD, National Archives and Records Administration [hereafter NARA], T 77/214, Ferdinand Friedensburg, 'Die deutsche Roh- und Treibstofflage, Abgeschlossen am 3.10.1940'. The latter source provides the figure for nickel consumption (on the basis of August 1939). More accurate than the IIC's consumption estimates were its stock estimates, even though there were also cases in which the IIC massively underestimated the actual size of stock, as with tin. On IIC's reliance on expert opinion, see NARA, RG 243, Box 895, Folder 134a-24, United States Strategic Bombing Survey, 'Special Paper No. 5: An Appraisal of Pre- and Post-War Intelligence', p. 59.

64. BArch, R 2/17606, 'Der Leiter der Reichsstelle für Wirtschaftsausbau, Richtlinien für die metallerzeugende, metallverarbeitende und metallverbrauchende Industrie, Sachgebiet Leichtmetalle', July 1938.

and two-thirds of the Wehrmacht's pre-war copper consumption.[65] Early substitution plans had been realised only hesitantly and to a limited extent, for several reasons.[66] First, tests took time.[67] Secondly, recurring periods of abundant allocation of metals seem to have reduced the incentive to implement such measures.[68] In addition, the Wehrmacht, a conservative and quality-oriented institution, occasionally refused to use ammunition made of steel instead of brass. Moreover, the substitution of copper with steel in the case of ammunition required new machine tools, which would have to be produced by the German machinery industry, which had no spare capacity.[69] Finally, armament producers were probably also reluctant to use substitutes because companies normally preferred to process raw materials with which they had experience.

Yet, in June 1939, a substitution plan for ammunition production to be implemented in case of war was set up on behalf of Hitler.[70] In the following weeks, Hermann Göring, in his function as head of the Four-Year Plan administration, ordered surveys to identify additional substitution possibilities.[71] By late August 1939 the implementation of copper-conserving measures in the armament industries was considered top priority on a list of measures to be carried out immediately in the field of armaments production.[72] On 31 August, the immediate conversion to steel shells for use in anti-aircraft guns was ordered. When the war started, many additional substitution measures for scarce metals (for example, in shells, bullet cores, detonators, and driving bands) were ready to be implemented in the production process.[73] In order to fully exploit these substantial substitution possibilities, 3,300 new machine tools were required.[74]

65. BArch, RW19/3076, fo. 4, 'Rohstoffversorgung der Wehrmacht', 1937–30 June 1939.

66. For estimates of the substitution potential in armament production in 1936, see BArch, RW 19/1911, fos 7–9, Reichskriegsministerium (RKM) to Oberkommando des Heeres (OKH), Reichminister der Luftfahrt (RdL) and Oberfehlshaber der Luftwaffe (ObdL), 9 Nov. 1936, 'Betr. Sparmaßnahmen'. For measures implemented, see, for example, BArch, RW 19/984, fos 15–16, note, 17 May 1939.

67. BArch, RL 3/2389, fo. 185, Heereswaffenamt (HWA) to Göring, 3 Feb. 1938; fo. 194, Nachschubamt to different authorities, 3 Apr. 1939; fo. 197, Generalquartiermeister to different authorities, July 1939.

68. BArch, RL 3/2389, fo. 62, Generalluftzeugmeister, Technisches Amt, subdepartment II/IV, 'Material für Vortrag beim Generalfeldmarschall, Betr.: Stand der Umstellung auf Magnesium und Stahlhülsen bei Flakmunition', 26 Aug. 1938; fo. 188, Generalluftzeugmeister, internal letter, 17 June 1938; T. Sarholz, *Die Auswirkungen der Kontingentierung von Eisen und Stahl auf die Aufrüstung der Wehrmacht von 1936 bis 1939* (Technische Univ. Darmstadt diss., 1983), pp. 229, 347.

69. BArch, RH 3/251, fo. 200, Thomas, Wehrwirtschaftsstab, 'Die deutsche Rüstungslage', 16 Aug. 1938.

70. BArch, RW 19/1, fos 284–300, OKH to Oberkommando der Wehrmacht (OKW), 12 Sept. 1939.

71. BArch RW 19/334, fos 231–2, Wochenbericht ('weekly report'), 7–12 Aug. 1939; fos 247–8, Wochenbericht, 21–26 Aug. 1939.

72. BArch, RH 15/153, fos 1–7, OKH to OKW, 23 Aug. 1939; fo. 32, Göring to OKW, 11 Sept. 1939. BArch, RL 3/2389, fo. 198, Befehl Nr. 6771, 'Einführung von Stahlhülsen', 31 Aug. 1939.

73. Sarholz, *Auswirkungen*, p. 437; BArch, RL 3/2389, fo. 136, Generalluftzeugmeister, Technisches Amt, note, 28 Mar. 1939; Müller, 'Mobilisierung', p. 457.

74. This was, given the total annual number of machine tools manufactured by the German industry (almost 200,000), a rather small number: USSBS, *Effects of Strategic Bombing*, Appendix, p. 224, Table 26.

Not only on the demand side, but also on the supply side, the Nazi regime soon implemented a new policy. One major change was increasingly to import ores or scrap instead of more expensive refined metals.[75] As a consequence, the capacities of German smelters and refineries, normally subsidised by the state, had to be increased significantly.[76] For example, the output of German copper refineries more than doubled between 1928 and 1938, and whereas in 1928 only 36 per cent of the copper consumed in Germany was refined in German smelters, the share in 1937 was 78 per cent.[77] One reason for the change of import composition was Germany's chronic lack of foreign currency.[78] Yet the expansion of smelting and refinery capacity, nearly completed in 1938/9 in the eyes of the German war planners, served not only to save foreign currency but also to provide capacity reserves in the event of war.[79] This was a lesson of the Great War, when Imperial Germany, which had predominantly imported metals rather than ores before 1914, had had to spend years expanding its smelters and refineries.[80]

In order to utilise this capacity, the Four-Year Plan administration planned to exploit, as during the Great War, two hidden reserves.[81] The first hidden reserve consisted of metal items still in use, such as church bells and copper pans, which were supposed to be mobilised during a war. Hitler himself emphasised this resource in his memorandum on autarky: 'War makes possible the mobilisation of all metal available. Because: this is then not an *economic problem*, but a *question of will*. And the National Socialist State leadership would possess the will, and also the resolution and the toughness, to solve these problems in the event of war. But it is much more important to prepare for war in time of peace!'[82] This emphasis on 'metal mobilisation' as a significant source of supply in the case of war was a conclusion of the secret surveys mentioned above; it also mirrors the findings of the publications of former employees in the war economy administration of Imperial

75. See, for example, H. Kehrl, *Krisenmanager im Dritten Reich: 6 Jahre Frieden—6 Jahre Krieg. Erinnerungen* (Düsseldorf, 1973), pp. 58–9.

76. On these subsidies, see Scherner, *Industriepolitik*, pp. 53–67; BArch, RW 19/333, fo. 305, Wochenbericht, 21–26 Nov. 1938; BArch, RW 19/334, fo. 91, Wochenbericht, 13–18 Mar. 1939.

77. Scherner, *Industriepolitik*, p. 233; BArch, R 2/15412, fos 176, 194, 'Metallgesellschaft Aktiengesellschaft, Statistische Zusammenstellungen'.

78. See, for example, Banken, 'Die wirtschaftspolitische Achillesferse', p. 206.

79. BArch, R 3112/24, fos 2, 15, Reichsstelle für Wirtschaftsausbau (RWA), 'Sofortmaßnahmen im Mob-Fall aufgrund der heutigen Versorgungslage auf den Rohstoffgebieten', Apr. 1938; R 3112/36, 'Bericht über den Industrieausbau im Jahre 1938 im Rahmen des 4-Jahresplans', Jan. 1939. For the objective of the war planners, see BArch, R 3112/165, fos 16–17, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan, Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'.

80. BArch, RH 61/843, fos 102–43, 'Auszug aus Lindig "Die staatliche Bewirtschaftung der Nichteisenmetalle im Kriege"'; Wiedenfeld, *Organisation*, pp. 23–44.

81. BArch, R 3112/165, fos 2–3, 9, 14–18, 32, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan, Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'.

82. Author's translation. Quoted in Treue, 'Denkschrift', p. 207; italics original.

Germany.[83] One further lesson which the German authorities drew from the experience of the Great War was not only to expand recycling capacities but also to foster recycling R&D.[84]

The second hidden reserve was German mining. In 1934, the German administration had implemented a new subsidisation scheme for domestic non-ferrous metal mines, aiming to expand production in order to tackle Germany's balance of payments problems.[85] The expansion of German mining output was still being pursued in 1936, when the Third Reich faced a new balance of payments crisis. Hitler demanded in his memorandum on autarky that German mining output should be expanded at all costs.[86] Yet it seems that, in the course of the following two years, Hitler's demand was modified, probably because, after years of significant price increases, metal prices started to drop substantially after the spring of 1937, making imports cheaper.[87] Contrary to statements that were still being made in 1936, maximisation of the mining output was no longer the core objective, having been modified by two principles. One clear-cut principle was to increase the absolute output by significant margins only in the case of those metals and mines in which the cost difference from the world market price was comparatively small.[88] A second criterion was that output should only be increased substantially where ores were abundant. Both criteria were fulfilled in the cases of lead and zinc, whose mining output was massively expanded.[89] If these criteria were not met, however, German ores were to be preserved as 'a last reserve' which should only be used in case of war.[90] In peacetime one should concentrate on successfully

83. Scherner, 'Lernen und Lernversagen'. See also the extracts from a comprehensive survey of metal mobilisation during the Great War, written in 1934, BArch, RH 60/9, 'Kriegswirtschaftliche Erfahrungen, Mobilisierung von Sparmetallen'.

84. Wiedenfeld, *Organisation*, p. 26; Maier, *Forschung als Waffe*, pp. 428–9, 612. In addition, even in peacetime, the recycling of domestic scrap expanded during the second half of the 1930s. For details about the systematisation and centralisation of scrap collection in Nazi Germany, see Reichskommissar für die Altmaterialverwertung, *Anordnungen und Richtlinien der Geschäftsgruppe Rohstoffverteilung und des Reichskommissars für die Altmaterialverwertung für die Zeit vom November 1936 bis Februar 1940* (Berlin, 1940).

85. Scherner, *Industriepolitik*, pp. 53–67.

86. Treue, 'Denkschrift'.

87. BArch, R 3102/3697, 'Monatsberichte über die Lage des Metallerzbergbaus', Jan. 1935 to Dec. 1938.

88. BArch, R 3112/165, fos 31, 38, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan, Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'; BArch, R 2/15412, fos 134–9, Reichswirtschaftsministerium (RWM) to Reichsfinanzministerium (RFM), 29 Aug. 1938.

89. The German statistical office assessed the lead and zinc ores available in Germany as 'significant'. See, for example, Statistisches Reichsamt, *Statistisches Jahrbuch für das Deutsche Reich 1941/42* (Berlin, 1943), p. 6.

90. See, for example, BArch, R 3112/165, fos 30–32, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan. Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'; R 3112/169, 'Ministerpräsident Göring zum Vierjahresplan', transcript of speech, early 1939. Preserving ores as a war reserve was also a commonplace in contemporary publications; see, for example, Wiedenfeld, *Organisation*, p. 61.

exploring German ores for future exploitation.[91] In wartime, mining should be increased to the extent which had been predetermined for each mine.[92] The purpose of metal stocks was mainly to bridge the supply gap between the outbreak of war and the point of time when the hidden reserves, i.e. German ores and metals to be recycled, could be mobilised.[93]

The regime was quite aware that the non-ferrous metal sector differed in one decisive point from most other sectors such as oil. No quasi-perfect synthetic substitutes were possible. Thus, exploiting the available natural resources, that is, German ores, in order to decrease import dependency during peacetime would leave less for wartime. In other words, the Nazi regime could not have its cake and eat it. To solve this trade-off, it decided at least from late 1937 to postpone a full exploitation of German mines until wartime. In the light of these intentions, the fact that German import dependency remained more or less unchanged during the 1930s does not suggest, as some scholars claim, that the non-ferrous metal policy was a failure.[94] This interpretation is confirmed when taking a look at the exploration activities. From 1934 explorations on German soil had to be reported to the state authorities and many explorations were subsidised or even carried out by the state (about a hundred up to 1936 alone), with the main purpose of creating reserve capacities.[95] From 1934 Wilhelm Keppler headed these explorations, first as Hitler's 'commissioner of raw materials production', then directly under the auspices of the Four-Year Plan authority, and from 1939 as president of the newly established Reichsstelle für Bodenforschung (Reich Exploration Agency).[96] In 1938 metal exploration was accelerated, and the focus shifted to those projects where mining could be started in a comparatively short period of time.[97] Generally, the exploration policy was quite successful over

91. W. Tomberg, 'Die Sicherung der Versorgung als Hauptaufgabe der Wehrwirtschaftspolitik', *Der Vierjahresplan. Zeitschrift für nationalsozialistische Wirtschaftspolitik*, iii, no. 17 (1939), p. 1024.

92. BArch, R 3101/31014, fo. 60, 'Kriegsaufgaben des Metallerzbergbaus für die Jahre 1940 bis 1942'.

93. BArch, R 3112/165, fos 33–4, 'Löb zur Nichteisenmetall-Wirtschaft im Vierjahresplan, Vortrag gehalten am 16. November 1937 im Amt für deutsche Roh- und Werkstoffe'.

94. See for example Volkmann, *Vorbereitung*, p. 310.

95. BArch, R 2/16103, fos 69–83, 'Rechenschaftsbericht anläßlich Übernahme der Aufgaben des Rohstoff-Büros des Beauftragten des Führers und Reichskanzlers für Wirtschaftsfragen, Keppler, durch den Vierjahresplan', 12 Oct. 1936.

96. Hanover, Bundesanstalt für Geowissenschaften und Rohstoffe Archiv [hereafter BGR-Archiv], /0008145, 'Mineralogische Studiengesellschaft Freiburg E.V., Metallspuren im Deutschen Sedimentgesteinen, Erster Bericht', 18 Mar. 1938; *Der Vierjahresplan. Zeitschrift für nationalsozialistische Wirtschaftspolitik*, iii, no. 7 (1939), p. 529. On the foundation of the Reichsstelle für Bodenforschung, see T. Kockel, *Deutsche Ölpolitik, 1928–1938* (Berlin, 2005), pp. 306–8.

97. BArch, R 3101/15421, fos 72–3, Reichswirtschaftsminister to Reichsfinanzminister, 18 July 1938; R 3112/24, fos 2, 15, RWA, 'Sofortmaßnahmen im Mob-Fall aufgrund der heutigen Versorgungslage auf den Rohstoffgebieten', Apr. 1938.

time.[98] For example, in the case of nickel, the known metal content of German ores rose rapidly during the last years before the war, from 20,000 tons in 1936 to 40,000 tons in 1939.[99] On the eve of the Second World War, German war planners knew that German soil held expensive (in terms of extraction cost) but abundant (in terms of temporary supply coverage) ores.[100] In the case of mining and ore reserves, too, the Nazi regime implemented measures of deception. From 1936 on, German authorities hid the extent of newly explored ore reserves as well as information about the metal content of ores mined in Germany.[101] The official Statistical Yearbook, which usually covered such aspects in detail, neither mentioned the existence of the huge, newly discovered copper ore reserves in Lower Silesia nor included the ore reserves of these mines in Germany's official copper reserves.[102] The British IIC seems not to have been aware of this potential either, as its wartime mining predictions simply extrapolated from German peacetime output;[103] at the very least it did not believe that these reserves would play a role before the war was over.

To conclude this section, on the supply side Germany's pre-war metal policy focused especially on preparing for the exploitation of hidden reserves in the case of war. This policy entailed costs, especially with regard to the enlargement of smelters and refineries and the exploration of German mines. If we add investments in the production of light metals which served largely as substitutes for non-ferrous metals, it becomes clear that up to the beginning of the war only the synthetic fuel industry received more investment, signalling the importance that metals had in the war preparation plans of the Nazis.[104] Considering all the measures both on the demand side and on the supply side that were put in motion during the 1930s, one has to conclude that scholarly opinion regarding this vital field is mistaken. Rather than being a

98. BGR-Archiv, /0059782, 'Ergebnisse der deutschen Lagerstättenforschung', 1940.

99. BArch, R 3101/30339, fos 26–45, 'Über die Nickelvorräte bei Frankenstein und die Aussichten der Erschliessung weiterer Nickelerzvorkommen in den schlesischen Serpentinen', 18 Sept. 1936; and below, Appendix, Table A1.

100. Ibid. Notice that the annexation of the Sudetenland in 1938 increased Germany's reserves of tungsten and tin ores significantly.

101. BArch, R 13 I/601, 'Aktenvermerk über die Besprechung mit der gewerblichen Wirtschaft über Pressefragen am Freitag dem 18.12.1936, 16.30 Uhr im Reichswirtschaftsministerium'; R 3101/31287, fos 176–7, 'Richtlinien für die Veröffentlichungen von Wirtschaftszahlen im Bergbau und Mineralölwirtschaft', 1936, and fo. 205, note, 20 Nov. 1936.

102. On the newly discovered copper fields, see Table A1 below, n. j. Yet, for unknown reasons, Keppler published in early 1939 an article in the official magazine *Vierjahresplan*, in which he revealed the copper reserves in this new mine. W. Keppler, 'Die Erforschung des deutschen Bodens', *Der Vierjahresplan. Zeitschrift für nationalsozialistische Wirtschaftspolitik*, special issue, no. 1/2 (1939), pp. 38–9.

103. The National Archives, T 160/846, Department of Overseas Trade (I.I.C.), ICF/284, 'Germany: Supplies of Foodstuffs and Raw Materials in War', Appendix I, 1 June 1939.

104. For investment data, see J. Scherner, 'The Beginnings of Nazi Autarky Policy: "The National Pulp Programme" and the Origin of Regional Staple Fibre Plants', *Economic History Review*, lxi (2008), pp. 867–95, at 870; BArch, R 2/78, fos 91–3; Scherner, *Industriepolitik*, p. 234; Scherner, 'Staatliche Förderung', p. 384.

failure, war preparation in this field was sophisticated, informed and systematic. The examination of the pre-war metal policy of Nazi Germany suggests, too, that Hitler was indeed preparing for a major war, and not for a series of short wars.

III

This section quantifies, as far as possible, the expectations of the German war planners regarding the monthly coverage of Germany's estimated wartime consumption in the light of its war preparations and a potential sea blockade. As will be shown, on the eve of the Second World War they must have anticipated that a long (not endless) war would be feasible in terms of the supply of metals. In contrast to previous work on this topic, I do not employ the existing contemporary surveys of some subordinate government agencies. A closer inspection of these studies reveals that they are based on incomplete and inconsistent data as well on problematic assumptions (as they themselves sometimes admit in the fine print).[105] Their findings represent in all cases very pessimistic lower limits. This may be partly explained by the specific agenda of their authors.[106] More important still seems to have been the secrecy typical of the Third Reich, rooted in the desire to disguise the extent of war preparations. This tactical campaign of deception, which is well known with regard to other fields of war preparation, not only led to restrictions on the publication of sensitive data in the German Statistical Yearbook, as mentioned above, but also limited the information flow among public entities, which even included highly placed Nazis.[107] For example, the Reichsamt für wehrwirtschaftliche Planung (Reich Planning Office for the Military Economy) had no

105. All these surveys and projections employ only a fraction of the existing stocks and consider measures to temporarily increase self-sufficiency (by mining or by metal mobilisation) only partly, if at all. Some of the studies employed also inflated consumption levels, as they sometimes admit. For these surveys and projections, see, for example, BArch, R 3112/53, Reichsamt für Wirtschaftsausbau, 'Möglichkeiten einer Großraumwehrwirtschaft unter deutscher Führung', Aug. 1939; RW 19/2347, fos 1–16, Wehrwirtschaftsstab, 'Rohstoffeinsatz bei der Wehrmacht im IV Quartal 1939', 27 Sept. 1939; RW 19/2346, Wehrwirtschafts- und Rüstungsamt, 'Zahlen-Zusammenstellung zur Beurteilung der Rohstofflage bei einer längeren Kriegsdauer', 3 Nov. 1939; RW 19/351, Wehrwirtschaftsamt, 4 Nov. 1939. A report sent by the RWM to Göring on 29 Aug. 1939 (NARA, RG 243 Box 784, F 110 c9, 'Rohstofflage im Mobfall, festgestellt Juli 1939'), which is also used in the literature (see, for example, USSBS, *Effects of Strategic Bombing*, p. 121, Table 13), has similar shortcomings.

106. A specific agenda may have played a role in the case of the projections made by the economic branch of the Wehrmacht; its head, General Thomas, was not only notoriously pessimistic, but aimed also in the autumn of 1939 to prevent Hitler from launching an offensive war against the Western powers: Fröhlich, *Wehrwirtschafts- und Rüstungsamt*, pp. 171, 322.

107. With regard to Germany's foreign currency reserves, investments, military budget and structure of industrial production, see, for example, R. Banken, 'Die nationalsozialistischen Goldreserven und Devisenpolitik, 1933–1939', *Jahrbuch für Wirtschaftsgeschichte*, xliv, no. 1 (2003), pp. 49–78; R. Fremdling and R. Stäglin, 'Verschleierung mit Statistik: Kriegswirtschaftliche Desinformation im Nationalsozialismus', *Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte*, xcix (2012), pp. 323–35; Scherner, 'Armament in the Depth'.

access to data on the amount of strategic raw material stocks available to the government.[108] Given the weaknesses of the existing surveys, I use scattered information which was available on the eve of the war on expectations concerning the amount of imports, consumption, and the effects of substitution and conservation in the event of war; on supply by metal mobilisation and other sources of recycling; on supplies from German ores; and on German metal stocks in September 1939. The implicit assumption is that the higher echelons of the Nazi regime, especially Göring and Hitler, had access to all this information or were at least informed about the general situation in the field of metals. This seems to be very probable not only in the case of Göring as head of the Four-Year Plan administration, but also in the case of Hitler. Before and during the war the 'Führer', who generally had an active interest in questions regarding raw materials,[109] insisted on receiving quantitative information about all aspects of the war economy, sometimes even detecting calculation mistakes himself, and was fully informed about raw material allocation, about which he had the final say.[110] Evidence suggests that Hitler had a profound understanding of the situation with regard to non-ferrous metals: the question of how to master the non-ferrous metal supply played a prominent role in his reasoning about economic preparations for war, and he repeatedly intervened in metal policy, especially in the months leading up to the war. For example, non-ferrous metals are explicitly mentioned in three key pre-war documents: in the secret memorandum about the Four-Year Plan; in the Hossbach Protocol of late 1937, in which Hitler outlined his war plans;[111] and in a meeting with the Wehrmacht on 22 August 1939, when he was contemplating whether a blockade by the Western powers in case of German aggression against Poland could harm Germany or not.[112] Moreover, after having demanded in the summer of 1938 that non-ferrous metal consumption be reduced by additional substitution measures and R&D in this field, so that German consumption needs could be met by German sources, he insisted in June 1939 on establishing

108. BArch, R 3101/8437, RWM, internal letter, 18 June 1938; R 3102/3139, fo. 17, Reichsamt für Wehrwirtschaftliche Planung (RwP), 'Bericht des Referats Rohstoffverteilung über die Bilanzen 1936', Dec. 1938. Also the IIC noted in summer 1939 the secretiveness and restricted information flow concerning raw materials among public entities, including high-ranking Nazis: Wark, *Ultimate Enemy*, pp. 181–2.

109. R.J. Overy, *Hermann Göring: Machtgier und Eitelkeit* (2nd edn, Munich, 1990), p. 76.

110. See, for example, Müller, 'Mobilisierung', p. 527; Tooze, *Wages of Destruction*, pp. 311–13; Scherner, 'Lernen und Lernversagen', p. 265; V. Ullrich, *Adolf Hitler: Biographie. Die Jahre des Untergangs, 1939–1945* (Frankfurt am Main, 2018), p. 71.

111. *Trial of the Major War Criminals before the International Military Tribunal*, XXV: *Documents and other Material in Evidence* (Nuremberg, 1947), pp. 403–13, at 404 (Doc. 386-PS, memorandum by Colonel Hossbach, 10 Nov. 1937).

112. *Trial of the Major War Criminals before the International Military Tribunal*, XXVI: *Documents and other Material in Evidence* (Nuremberg, 1947), pp. 338–44, at 342–3 (Doc. 798-PS, address by Hitler to the Commanders-in-Chief, 22 Aug. 1939).

a substitution plan for ammunition production, to come into effect in case of war.[113] This indicates that Hitler was so fully informed of the scarce metal situation that he knew that additional conservation could be implemented. In July, it was Hitler himself who insisted that the German economy should adapt to a situation in which only non-ferrous metal imports from friendly neighbour countries could be expected.[114]

So what did the expectations of German war planners look like? Let us first discuss the consumption side. I do not use the existing pre-war consumption projections for the case of war because these figures, as far as they concerned the prospective Wehrmacht consumption, were massively inflated.[115] It was for this reason that the authors of the United States Strategic Bombing Survey (USSBS), who in summer 1945 tried to calculate the monthly consumption coverage of Germany's stocks, chose the consumption data for the last quarter of 1939 as an indicator for anticipated wartime consumption. I follow the choice of the USSBS with some modifications. One of these concerns the inclusion of the substitution and conservation potential for the metals considered in this article as expected at the end of the 1930s.[116] As mentioned above, substantial substitution and conservation possibilities had been prepared for the case of war. Given that we have data on the expected lower limits of substitution effects for 1940, I use these reduced levels of expected consumption as a proxy for expected wartime consumption from 1940 onwards. By doing so, I implicitly assume that later substitution and conservation effects would be offset by an expansion of wartime production. This is probably a conservative assumption. In contrast to the size of armament production, a significant expansion of which compared to the levels early in the war seemed not to be expected by the German planners,[117] very substantial future substitution and conservation effects in the field of metals were predicted. Once the war began, the Wehrmacht estimated that the existing and known substitution

113. BArch, RW 19/94, 'Stand der deutschen wirtschaftlichen Lage', 1 Aug. 1938; RW 19/1, fos 284–300, OKH to OKW, 12 Sept. 1939.

114. Müller, 'Mobilisierung', pp. 427, 429; BArch, RW 19/334, fo. 207, Wochenbericht, 10–15 July 1939.

115. See, for example, Sarholz, *Auswirkungen*, p. 260; Fröhlich, *Wehrwirtschafts- und Rüstungsamt*, pp. 291–2.

116. For additional, but rather minor modifications see sources, see Table A1 below.

117. For example, even though war planners at the time believed that the amount of steel available would be (under favourable conditions) sufficient to fulfil the wartime demand of the Wehrmacht, as it was in 1939, they were also convinced that this would be an upper limit. In their eyes, the problem would be iron ore, where the loss of access to some important foreign supply sources could not be fully replaced by an expansion of German mining. BArch R 3101/11617, 'Zur Frage des Produktionsrückgangs im Kriegsfall—der Engpaß des Eisens', 12 Aug. 1939. War planners believed, too, that the level of German pre-war armament production would have been already very high compared to the situation in 1914 and compared to the maximum level achievable during a war. *Trial of the Major War Criminals before the International Military Tribunal*, XXXVI: *Documents and other Material in Evidence* (Nuremberg, 1947), pp. 112–32, at 116, 120 (Doc. 028-EC, Address of General Thomas to members of the German Foreign Office, 24 May 1939); BArch, RH 8/1122, Vortragsnotiz WA, 'Betr.: Mob-Nachschubversorgung an Waffen und Munition (Vergleich mit der Weltkriegshöchstleistung)', 31 Aug. 1939.

possibilities could reduce the specific consumption of copper, tin and nickel per output unit of armaments by up to 90 per cent.[118] These estimates were not exaggerated from an ex-ante perspective. Whereas the copper–steel ratio in Nazi Germany's pre-war ammunition production was 4 per cent, the same ratio in April 1918 was significantly lower at 1.8 per cent (and could have been lowered further), indicating that there was still ample room in 1939 for exploiting further conservation and substitution measures.[119] Yet the Wehrmacht could not expect fully to exploit the substitution potential mentioned above in the short run. In the case of copper, for example, the authorities were well aware that massive substitution in ammunition production could not be realised before spring 1941 because of a lack of machine tools.[120] Moreover, the still too limited capacities of German aluminium plants (not a lack of bauxite) allowed a supply of only two-thirds of the aluminium necessary in order to substitute copper at the beginning of the war.[121]

On the supply side, we have to examine different sources. One of these was metal mobilisation. At first glance one might expect a lower amount of metals to have been available than during the Great War, given that consumption had been restricted after 1934. Yet a closer look suggests rather the opposite, as the institutions involved in metal rationing should have easily been able to tell. The most important, if only partly tapped, source by far of tin mobilisation during the Great War had been church bells. These, however, had been fully replaced after the Great War and so this source of supply still existed. Moreover, the relatively lower yield of household copper mobilisation would have been more than offset by the huge copper potential of power lines as a result of the massive electrification of the 1920s.[122] In the case of nickel, too, the mobilisation potential was far higher than during the Great

118. BArch, RW 19/1, fo. 282, Wehrwirtschaftsstab, Rohstoffabteilung (Wi Ro), subdepartment II, 'Vermerk über die Engpaßgebiete auf dem Metallgebiet', 9 Sept. 1939.

119. For data for April 1918, see BArch, R 8752/11, 'Aufstellung der im April 1918 zugewiesenen Metallrohstoffe'. At this point in time, not all factories producing ammunition had already substituted copper with steel. See, for example, R. Weyrauch, *Waffen- und Munitionswesen* (Berlin, 2016), p. 253. For the late 1930s, see Table A2 below.

120. BArch, RW 45/13, 'Außenhandel und Wehrwirtschaft, Niederschrift über die zweite Sitzung des Außenhandelsausschusses des Beirats der Reichsbank', 19 Dec. 1939; RH 15/160, fo. 256, OKH, 'Denkschrift über die Steigerung der Munitionsfertigung auf Grund der Führerforderung vom 12. Dezember 1939', 10 Jan. 1940.

121. BArch, R 3112/13, note, 19 Dec. 1939; R 3112/150, Dr Eberhard Neukirch, 'Die Entwicklung des Leichtmetallausbaues im Vierjahresplan mit besonderer Berücksichtigung des grossdeutschen Freiheitskampfes ab 1939', p. 58. The Germans expected to import bauxite sufficient to produce 225,000 tons of aluminium. BArch, RW 19/171, fo. 208, 'In welchem Umfang kann im Fall eines europäischen Kriegs die Einfuhrversorgung Deutschlands aufrechterhalten werden', 8 May 1939. In addition, they disposed of very large bauxite stocks; see L. Budraß, 'Ideology and Business Strategy: Assessing Nazi Germany's Different Approaches to the Supply of Light Metals to the Luftwaffe', in H.O. Frøland, M. Ingulstad and J. Scherner, eds, *Industrial Collaboration in Nazi-Occupied Europe: Norway in Context* (London, 2016), pp. 37–63, at 47.

122. *Der Vierjahresplan. Zeitschrift für nationalsozialistische Wirtschaftspolitik*, special issue, iii, no. 1/2 (Jan. 1939), p. 66. Between 1925 and 1929, the capacity of German electricity producers increased by 50 per cent. Statistisches Reichsamt, *Statistisches Jahrbuch für das Deutscher Reich für 1931* (Berlin, 1931), p. 114.

War, because during the 1930s nickel coins had been explicitly minted in order to be smeltable in case of war.[123] Finally, recycling technologies had significantly improved over the last twenty years, not least due to a comprehensive R&D effort financed by German agencies.[124] Given all these considerations, I will use the known amounts for the representative metals which were considered to be realisable (nickel coins) or estimates made of the mobilisation potential during the Great War as an ex-ante proxy for the lower limit of metal mobilisation during the Second World War.[125] Note that the IIC, with the exception of nickel in coinage, seems to have ignored the possibility of metal mobilisation as an important additional domestic supply source.[126]

Besides the metal mobilisation I must consider recycling from 'normal' scrap and so-called battlefield scrap. The latter had been important during the Great War and was seen by the German authorities as an additional prospective supply source.[127] In the case of 'normal' scrap, I assume, similarly to the German authorities, that the pre-war recycling quotas (in per cent of consumption) of the respective metals could be maintained in the event of war. In the case of battlefield scrap, I employ estimates from the Wehrmacht.[128] In the case of the existing stocks, the quantification relies on well-known data. It should be emphasised that Germany's metal stocks in 1939 were not lower—as one might expect, seeing the chronic balance of payments problems during the 1930s, and as obviously less informed German agencies seem sometimes to have believed—but, thanks to German stockpiling efforts, rather similar or even bigger, in absolute terms, than at the beginning of the Great War. Even in relative terms, that is, in terms of the monthly coverage of wartime consumption, the pre-war stocks in 1914 were not significantly bigger than those in 1939; in the case of copper, for example, stocks in 1914 (around 150,000 tons) covered the consumption of ten months, whereas the stocks in September 1939 (194,000 tons) covered almost nine months.[129]

123. BArch, RW 19/1595, fos 220–21, 'Geldanforderungen aus dem Bereich des Generalbevollmächtigten für das Haushaltsjahr 1936', Jan. 1936; R 3112/24, fo. 16, RWA, 'Sofortmaßnahmen im Mob-Fall aufgrund der heutigen Versorgungslage auf den Rohstoffgebieten', Apr. 1938. On the amount of nickel mobilised during the Great War, see BArch, RH 61/695, 'Metall-Mobilisierung'.

124. Maier, *Forschung als Waffe*, pp. 428–9, 612.

125. See Table A1 below.

126. The National Archives, T 160/846, Department of Overseas Trade (I.I.C.), ICF/284, 'Germany: Supplies of Foodstuffs and Raw Materials in War', 1 June 1939.

127. BArch, RW 19/1, fo. 283, Wi Ro II, 'Vermerk über die Engpaßgebiete auf dem Metallgebiet', 9 Sept. 1939. On the Great War, see BArch, RH 61/1125, 'Die Kriegsbewirtschaftung der Metalle, 1. August 1914 bis 31. August 1916', pp. 31–7.

128. BArch, RW 19/2346, 'Zahlen-Zusammenstellung zur Beurteilung der Rohstofflage bei einer längeren Kriegsdauer', 3 Nov. 1939.

129. Consumption relates to the early months of the war. On German copper stocks in September 1939 and on consumption during the early months of the war, see Table A1 below. Stocks in August 1914 can be estimated by employing data about German stocks in May 1915 as well as consumption data and supply data between August 1914 and May 1915. For consumption data, see

In order to assess German mining potential, I use the information found in files of the German authorities in the late 1930s.[130] Göring and the higher echelons of the Four-Year Plan agency, and probably Hitler too, were regularly informed about explorations by Keppler, who was also Hitler's economic adviser.[131] In keeping with the pre-war expectations of Hitler and of German governmental agencies (as well as of the British), I also include imports from some neutral continental European countries and axis countries in the estimate.[132] The data for the various metals and the respective countries derive from secret estimates concerning German imports in the event of war made in 1939 on behalf of the Nazi regime.[133] These estimates assumed that re-exports from neutral countries, which had been important for Imperial Germany's metal supply during the first years of the Great War, would not be possible, or at least not something to rely on, in a future war. This assumption was probably based firstly on the expectation that Germany's opponents would have learned their lessons by implementing a very rigid system of monitoring right from the beginning of a future conflict, and secondly on the assumption that Germany's ability to finance imports would be more restricted than during the Great War because of its lower foreign currency reserves. These estimates assumed, too, that wartime metal imports from Scandinavia, Finland, Italy, the Benelux countries, the Baltic states and

Tröger, 'Technik in der Metallwirtschaft', p. 514 (first months of the war), and BArch, RH 61/248, 'Aus den Handakten von Professor Tröger, Metallverbrauch Deutschlands 1913–1918' (for 1915); for stock data in May 1915, see C.B. Denton, 'Metal to Munitions: Requisition and Resentment in Wartime France' (Univ. of California, Berkeley, Ph.D. thesis, 2009), pp. 51–2. For supply data, which includes German copper mining, recycling, and war loot in occupied countries and imports, see K. Klein Goldewijk and J. Fink-Jensen, 'Copper Production' dataset (1 Nov. 2014), available via *Clio Infra* (International Institute of Social History, 2010–), at https://clio-infra.eu/Indicators/CopperProduction.html (mining); P. Irrgang, *Deutschlands Kupferversorgung seit 1914* (Philipps Univ. Marburg diss., 1931), p. 51 (recycling quota); BArch, R 8737/365, 'Abrechnung der vom Kgl. Kriegsministerium überwiesenen Beutemetalle' (war loot); BArch, RH 61/248, 'Metalleinfuhr 1914'; BArch, RH 61/869, 'Einfuhr von Metallerzen und Metallen 1913–1918' (imports). For a cross-check, see L. Guichard, *The Naval Blockade, 1914–17* (New York, 1930), p. 267. Similar results can be produced for other metals. As an example of an pessimistic assessment of Germany's stocks, probably caused by the secrecy mentioned above, see the Reichsbank, which claimed that Germany's raw material stocks were only 20 per cent of the ones on the eve of the Great War: BArch, RW 19/171, fo. 204, 'In welchem Umfang kann im Fall eines europäischen Kriegs die Einfuhrversorgung Deutschlands aufrechterhalten werden', 8 May 1939.

130. This information clearly refutes claims that on the eve of the war German authorities were not aware of the existence of German tungsten ores, and that they assumed that the amount of German nickel ores was insignificant (Jäger, *Die wirtschaftliche Abhängigkeit*, pp. 86, 92–3).

131. See, for example, BArch, R 26 IV/5, fos 133–4, '23. Sitzung des Generalrats am 28.10.1938'.

132. On Hitler's expectations about metal imports in the case of war, see Müller, 'Mobilisierung', pp. 427, 429; BArch, RW 19/334, fo. 207, 'Wochenbericht', 10–15 July 1939. On British expectations concerning German import sources in the case of a blockade, see Hinsley, *British Intelligence*, pp. 65, 72.

133. BArch, RW 19/171, fo. 205, 'In welchem Umfang kann im Fall eines europäischen Kriegs die Einfuhrversorgung Deutschlands aufrechterhalten werden', 8 May 1939; R 19/567, fo. 125, Göring, 'Richtlinien zur Zusammenfassung aller Kräfte zur Steigerung der Fertigung', 29 Nov. 1939. For an example of several surveys carried out between summer 1938 and summer 1939, see BArch, R 3102/10082.

South-Eastern Europe, excluding re-exports, would be *at least* as high as in 1938 and could be financed by German exports.[134] This implies that our supply estimate represents a lower limit, especially because the German authorities expected to loot raw materials in conquered countries.[135]

In the following I examine whether, from the point of view of its metal supply, Germany would have been able to fight a 'long war'—that is, one as long as the Great War, or at least three years (as the British assumed in their long-war strategy).[136] For this purpose I calculate in a first step the residual between the expected annual consumption (considering the lower limit of substitution and conservation measures) and the expected supply covered by imports, stocks, and recycling in the broader sense. In a second step I examine whether this residual could have been covered by German mining. The results, as shown in detail in Table A1, suggest that German war planners, considering the experiences of the Great War and their hidden reserves, must have assumed on the eve of the war that a longer conflict should be feasible even in the case of a blockade.[137] Whereas the British assumed, as mentioned above, that Germany would run out of metals after fifteen to eighteen months, in reality a coverage between two and three times longer seems to have been possible. Theoretically, as Table A1 shows, this would have been the case for copper and nickel even without any German mining. While it is true that a very significant expansion of German mining would have been necessary in the case of tungsten (but not in the case of tin), this would have been possible. Nor would this expansion have taken more than about a thousand workers.[138] The mining expansion deemed to be required in order to cover German tungsten consumption for a war of three or almost four years was very similar in size to that put in motion in the summer of 1944, when Germany was cut off from its foreign tungsten supply sources.[139] It is worth noting, too, that the factor by

134. These estimates constituted the lower limits of the import expectations of the German war planners. In the case of copper, for example, for which 1938 imports from these countries reached 80,000 tons, they estimated imports up to 140,000 would be possible in the long run. BArch, R 3102/5927, RwP, 'Die rohstoffwirtschaftliche Bedeutung des Südostraums für die deutsche Wehrwirtschaft', Mar. 1939.

135. See, for example, Müller, 'Mobilisierung', p. 429. Potential imports from the Soviet Union (following the Molotov–Ribbentrop pact of 1939) as well as the supply implications of a 'blockade hole' in the East are not considered in these estimates.

136. For the British assumption, see D.C. Watt, 'British Intelligence and the Coming of the Second World War in Europe', in May, *Knowing One's Enemies*, pp. 237–70, at 251.

137. Note that, given the processing time required between the supply of raw materials to the factories and the delivery of armaments to the Wehrmacht, it would have been on average an additional six months before the armament output dropped.

138. BArch, R 3102/4143, 'Industrielle Produktionsstatistik—Jahreserhebungen für den Metallerzbergbau'. See also section IV of this article.

139. See section IV. Note that similar results could be produced in the case of molybdenum. In the case of chrome, it was assumed that south-eastern Europe could fully satisfy the German demand: BArch, R 3102/5927, RwP, 'Die rohstoffwirtschaftliche Bedeutung des Südostraums für die deutsche Wehrwirtschaft', Mar. 1939. Note, too, that the Nazi planners did not expect any supply problems in the case of manganese and antimony.

which peacetime mining would have had to be expanded is similar to the expansion factor during the Great War.[140]

Therefore, given these considerations, and the data as well as the estimates produced in Table A1, the Nazis very probably felt sufficiently prepared in, or were at least not too concerned about, the field of metals—which was certainly not the only factor in their risk assessment—even in the event that aggression against Poland resulted in a 'long' (but not endless) European war. This is especially true if one considers that Table A1 includes only the very lower limit of the expected effects of the substitution and conservation measures in the long run. Thus, in contrast to the commonly held belief of the Western powers at the time and of historians since, German stocks would neither solely nor predominantly determine Germany's metal consumption in a future war. Moreover, statements by Hitler and other Nazi leaders that Germany was actually well prepared for a blockade cannot be dismissed as propaganda in the case of these vital raw materials, as has often been stated in the secondary literature. Finally, as the data clearly shows, using large parts of the metal stocks in early 1940 to prepare the offensive against the Western powers did not imply, as some scholars believe, that Hitler took a very risky gamble—at least not in the case of non-ferrous metals—or that this decision would have prevented him from continuing the war had the offensive failed.

IV

All these programmes, prepared during the 1930s, were activated after the beginning of the war. The most spectacularly effective measure, as will be shown, was substitution and conservation. As mentioned above, scholars have long believed that wartime substitution measures were predominantly implemented after 1941. This interpretation seems to be corroborated—at least at first glance—by hard evidence. In the case of most metals, total consumption dropped after 1941 or remained by and large constant, in spite of the rising output of German industry, especially the massively increasing armament production.[141] Yet such rough indicators may be misleading for two major reasons. First, in early 1942 a new allocation system was implemented which greatly reduced the incentive to hoard metals illegally.[142] As a consequence, official consumption figures for the first half of the war may overstate

140. BArch, RH 61/843, fo. 141, Auszug aus Lindig, 'Die staatliche Bewirtschaftung der Nichteisenmetalle im Kriege'.

141. On consumption data, see USSBS, *Effects of Strategic Bombing*, pp. 263–4, Appendix, Table 83.

142. It stipulated—in contrast to the old one—that unused quotas did not expire after three months. In addition, a more draconian punishment in case of hoarding was implemented in 1942. On the new system, see BArch, R 3101/11701, fos 38–45, 'Vorschläge für eine Vereinfachung der Metallbewirtschaftung', 11 Apr. 1942; R 3101/11705, fos 251–4, 'Auswirkungen der Neuordnung der Metallbewirtschaftung', 12 Apr. 1943. G. Thomas, *Geschichte der deutschen Wehr- und Rüstungswirtschaft (1918–1943/45)* (Boppard am Rhein, 1966), p. 365; Overy, *War and Economy*, pp. 359–60, 369–70; Scherner, 'Lernen und Lernversagen', pp. 254–5.

actual consumption figures relatively more than those for the later period.[143] The second criticism with regard to rough indicators such as metal input per total armament output or per industrial production stems from the fact that the denominator of those indicators does not control for changes of the composition of output. Yet data unearthed in German archives widely overcomes the latter problem. This data covers, for most of the quarters between 1939 and mid-1943, the ratio between the allocation of various non-ferrous metals and the basic raw material of most armament goods—steel in the case of two major categories of armaments, ammunition as well as weapons and equipment (such as firearms, guns, tanks, and electrical equipment).[144] The data on ammunition in particular is useful for tracing substitution and conservation effects because shells are a comparatively homogeneous good, unlike the broader category of weapons and equipment (W&E).

Figure 1 provides some metal–steel ratios for both categories of armaments. For the sake of the readability of the figure, I selected only ratios for those scarce metals whose consumption in the respective category was quantitatively especially significant, compared to total German consumption. The ratios that are not shown here display similar trends. The data clearly suggests, in contrast to the usual narrative, that with regard to substitution there was continuous (though not always steady) progress during the war rather than a caesura in 1942. Figure 1 shows, too, that the substitution potential seems already to have been exploited to a significant extent before 1942, especially in the case of the originally very copper-intensive ammunition production. Moreover, one can see how the substitution measures in ammunition production, which had been prepared during the 1930s and which were implemented very quickly when the war started, had an immediate and massive effect, reducing the specific copper consumption by 40 per cent.[145] In the following year the substitution levels increased further, because machine tools necessary for the conversion of the ammunition industry were delivered to the factories as had been planned in 1939.[146] In the spring of 1941, the copper–steel ratio of ammunition production

143. German statistics measured consumption on the basis of how much of the rationed metals were called up by the companies and how official company stocks evolved. BArch, R 3102/6151; R 3101/11707, fos 62–3, Statistisches Reichsamt (StRA) to Reichswirtschaftsminister, 25 June 1942, and fo. 108, Reichsstelle für Metalle (RstMe) to Statistischen Zentralauschuß, 21 Sept. 1942; R 3101/30489, fo. 4, 'Allgemeine Erläuterungen'.

144. For this definition, see E. Leeb, *Aus der Rüstung des Dritten Reiches: Das Heereswaffenamt, 1938–1945* (Frankfurt am Main, 1958), p. 18.

145. Comparing copper/steel allocation data of the ammunition production in the first quarter of 1940 with the respective consumption requests of the Wehrmacht for October 1939 shows that the reduction was even bigger, at 59 per cent. See BArch, RW 19/2347, fos 7, 10, Wehrwirtschaftsstab, 'Rohstoffeinsatz bei der Wehrmacht im IV Quartal 1939', 27 Sept. 1939. For measures implemented in the following months to reduce copper consumption, see, for example, BArch, RW 19/338.

146. BArch, RH 15/160, fo. 256, OKH, 'Denkschrift über die Steigerung der Munitionsfertigung auf Grund der Führerforderung vom 12. Dezember 1939', 10 Jan. 1940; RW 45/13, 'Außenhandel und Wehrmacht, Niederschrift über die zweite Sitzung des Außenhandelsausschusses der Deutschen Reichsbank', 19 Dec. 1939. Thomas, *Geschichte*, p. 123

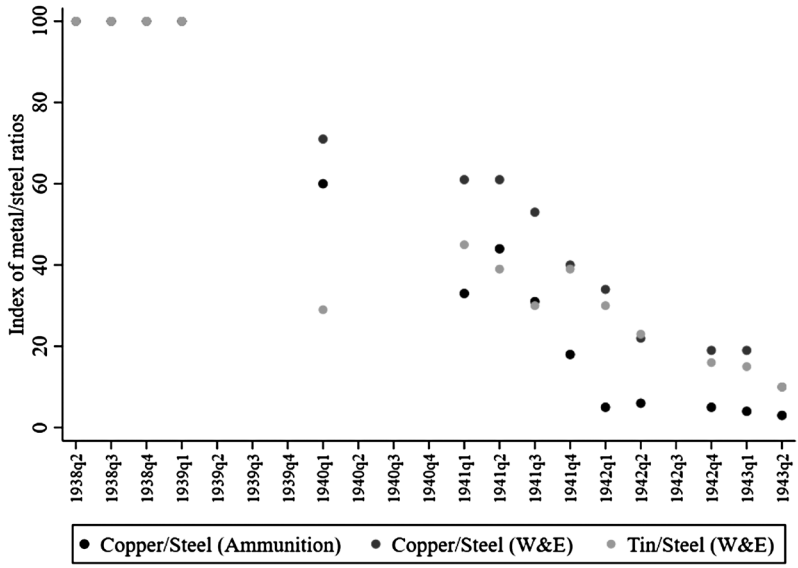

Figure 1. Substitution of copper and tin in armament production, 1938/9–43 (1938/9=100).

Sources: see Appendix, table A2.

matched that of April 1918 (1.8 per cent), before it dropped even further to 0.21 per cent in early 1942 and to 0.13 per cent in the spring of 1943.[147] Not only was the absolute specific copper consumption in ammunition production much lower during the Second World War, but the pace of the implementation was also much quicker. This should not surprise us in the light of the pre-war substitution R&D efforts pushed by German authorities. While it took four years during the Great War to reduce the specific consumption of copper in ammunition production by about 80 per cent, the same relative reduction was reached within two years of the outbreak of the Second World War.[148] Indeed, in the case of these two important categories of armaments production, the general unwillingness of the Wehrmacht (or at least important parts of it) to accept quality reduction,[149] and therefore also substitution and conservation measures, was already overcome or mitigated soon after the war had started, not only later. This was probably not simply due to orders to implement substitution measures at the beginning of the war and the repeated pressure exerted by Göring and Hitler to accelerate substitution and conservation of non-ferrous metals in armament

147. See Table A2 below.
148. On the Great War, see Tröger, 'Technik in der Metallwirtschaft', p. 524.
149. Generally on the quality orientation of the Wehrmacht, see Overy, *War and Economy*, pp. 199, 250, 347; Overy, *Göring*, pp. 271–2; Müller, 'Mobilisierung', pp. 603–4.

production in summer 1939 and the following winter;[150] rather, it was also a result of the drastic reduction in the allocation of most non-ferrous metals to the Wehrmacht, copper in particular, in the months before the war.[151]

Other fields of the war economy, and the figures for metals other than tin and copper, reveal similar patterns. This was the case for the massively increasing production of high-grade steels, essential for almost all armaments, as can be seen from the ratio between the consumption of steel alloys (that is, the quantities needed for production) and the output of high-grade steel. Here, too, substantial substitution measures were already implemented during the first half of the war, as the ratios, compared to the level in 1939, suggest (as shown in Table 3).[152] For example, in 1941, producing one ton of high-grade steel required only 34 per cent of the tungsten quantity that had been needed in 1939. At the same time, vanadium consumption and production increased massively.[153] To sum up, the data on wartime conservation and substitution confirms the high expectations the German war planners had in 1939.

Even though substitution certainly also had its negative effects, for example with regard to the quality of the products in many (but not all) cases, substitution played *the* pivotal role in overcoming the constraints imposed by the blockade. The volume of substitution of copper by steel in the ammunition production[154] and by aluminium alone (*c.*900,000 tons)[155] was one-and-a-half times that of the copper inflow from occupied countries and more than fourfold that of German copper stocks on the eve of the war.[156] The conservation and substitution of nickel during the war (54,000 tons) was, compared to pre-war levels,

150. On Göring's and Hitler's demands, see above; for pressure in winter, see, for instance, Müller, 'Mobilisierung', p. 459.

151. In the summer of 1939, these cuts seem to have prompted the army to forbid industry from using copper when developing new armaments. For examples, see HA Krupp, WA 40/259. On allocation data, see BArch, RW 19/3076, 'Rohstoffversorgung der Wehrmacht, 1937 bis 30.6.1939'.

152. See, for numerous additional examples, BArch, R 3112/96, Reichsamt für Wirtschaftsausbau, 'Eiseneinsparung und Einsparung von NE-Metallen', 1941; RH 8/10, 'Einsparungen von Mangelrohstoffen durch das HWA', *c.*1942.

153. USSBS, *Effects of Strategic Bombing*, p. 264, Appendix, Table 83.

154. The amount of copper substituted by steel is calculated by employing the copper/steel ratios given in Table A2 below. In the case of quarters for which no ratios are available, I use that from the previous quarter. Steel consumption relies on the data provided in BArch, RH 8/12. Data for 1941 IV and 1942 I are calculated by using the copper–steel ratios and the data given in BArch, RH 8/1424. The missing steel data for 1942 II as well as for the quarters from 1943 III to 1944 IV is estimated by multiplying the value of steel components consumed in the ammunition production (USSBS, *Effects of Strategic Bombing*, p. 283, Appendix, Table 112) by the ratio between the steel consumption and the consumption of steel components in 1942 I and 1943 II respectively.

155. The amount of copper substituted with aluminium is calculated by using the substitution ratio between copper and aluminium (BArch, 3112/100, 'Mobilisierung von Kupfer und Einsparung von Kupfer durch Aluminium', 27 Feb. 1942) and by assuming that the annual amount of aluminium allocated for copper substitution during the war, for which no data could be found, matched (as a lower limit) the one in 1939 as given by BArch, R 3112/13, note, 19 Dec. 1939.

156. For stocks and imports from occupied countries, see BArch, R 3/1797, 'Statistische Schnellberichte zur Kriegsproduktion'.

Table 3. Use of steel alloys in high-grade steel production, 1939–44 (1939=100).

	Tungsten[a]	Molybdenum[a]	Nickel[b]	Chrome[c]	Vanadium[d]
1940	57	57	95	92	135
1941	34	43	61	99	191
1942	<52	<43	47	79	219
1943	<24	<14	35	52	217
1944	<14	<11	32	48	191

Sources and notes: For high-grade steel production, see Jäger, *Abhängigkeit*, p. 305, table 47.

[a]Consumption data from 1942 on is an upper limit of consumption in high-grade steel production because allocations for other purposes, such as radio valves or light bulbs, are included. For 1939–41, see BArch, R 13/XII/601, fos 190–91, 'Verbrauch und Erzeugung von Ferromolybdän und Ferrowolfram'; for 1942–4, see BArch, R 3/576.

[b]Nickel consumption in 1939 is calculated by adding up the data given in BArch, R 3112/27, fo. 26, 'Nickel-Erzeugung und Verbrauch', and in BArch, R 3/576; for 1940–44, see BArch, R 3/576.

[c]For 1939, see BArch, R 13/XII/601, fo. 154, 'Verbrauch, Erzeugung, Bestand und Einfuhr von Ferrochrom'; for 1940–4, see BArch, R 3/576.

[d]1939 consumption data refers to the last quarter of the year. Data for 1944 are production data. For 1939, see BArch, R 3102/3249, Reichsamt für wehrwirtschaftliche Planung, 'Monatliche Rohstoffübersicht'; for 1940–43, see Jäger, *Abhängigkeit*, p. 297, table 45; for 1944, see BArch, R 3/1797, fo. 23, 'Statistische Schnellberichte zur Kriegsproduktion'.

even more than double that of the nickel stocks in September 1939 and the inflow from occupied countries combined.[157]

On the supply side, too, pre-war plans were activated. Immediately after the outbreak of war, the Reichsstelle für Metalle (the former Überwachungsstelle für Metalle) set up a programme for metal mobilisation.[158] It determined that only those measures should be carried out immediately for which no replacement was necessary, while measures entailing high (labour) costs per ton of metal mobilised should be postponed until—if ever—they were really needed.[159] However, this principle was—as a result of the experiences of the Great War—overruled by political considerations shortly thereafter. Measures thought likely to cause public unrest, such as the smelting of church bells or the requisitioning of household items, were to be postponed as long as possible. Even among the politically acceptable measures, the opportunity cost principle still dictated the order of collection. In the case of copper and tin in particular, the amount of metals mobilised

157. For stocks and inflows from occupied countries, see ibid. The amount of nickel substituted is calculated on the basis of Table 2.

158. Denton, 'Metal to Munitions', pp. 201–2.

159. For the following, see Scherner, 'Lernen und Lernversagen'.

in Germany was significant, covering respectively 17 per cent (210,000 tons) and 21 per cent (8,814 tons) of Germany's wartime consumption between 1940 and August 1944. In the case of both metals, this exceeded the amount mobilised during the Great War by a factor of two. The still-existing mobilisation potential for 1945 and 1946 was estimated to be up to 152,000 tons of copper and 5,800 tons of tin. In addition, the Germans activated their pre-war plans to collect scrap on the battlefields, which played an important role, relative to consumption, especially with regard to copper and aluminium.[160] For this purpose, as during the Great War, collection teams of soldiers were formed and monetary incentives provided.[161]

With regard to metal ores, the German war administration continued to carry out geological surveys and to explore and invest in standby mines.[162] Whether these standby capacities were fully exploited seems to have depended primarily on opportunity cost considerations. For most of the war, it was less expensive to expand the metal mobilisation of copper and tin, to plunder occupied countries, or to import these metals than to increase the mining of these ores.[163] As a consequence, a substantial expansion of mining was only considered when alternative supply sources were expected to be reduced or to run dry. This is apparent in the cases of tungsten and nickel, for which metal mobilisation measures played no role (tungsten) or a relatively minor role (nickel). In the case of tungsten, the exploration programme continued after the start of the war.[164] In 1942, the Reichsamt für Bodenforschung considered the German tungsten mines as rich as those of Portugal and Spain.[165] By the end of 1942, when annual German production amounted to only 180 tons *per annum*, standby capacities would have allowed an immediate annual output increase to 700 tons *per annum*, roughly one-third of German tungsten consumption in 1943.[166] Yet, up to mid-1944, a full utilisation of these standby capacities was not considered necessary. Only when it was certain that tungsten imports from the Iberian Peninsula, so far the main foreign source, would stop in the second

160. In the middle of the war, battlefield scrap accounted for about 5 per cent of Germany's copper consumption: BArch, RW 19/2336. Reclaimed aluminium constituted about 30 per cent of Germany's consumption in 1944: BArch, R 3/1797, fo. 14, 'Statistische Schnellberichte zur Kriegsproduktion'.

161. Thomas, *Geschichte*, p. 299. For the incentives during the Great War, see BArch, RH 61/1125, pp. 31–7, 'Die Kriegsbewirtschaftung der Metalle, 1. August 1914 bis 31. August 1916'.

162. Further exploration in the Lower Silesia fields led to a doubling of the expected copper content compared to the estimates made during the 1930s. See BArch, R 3101/31319, and R 3101/30365.

163. In 1941, Germany had to pay for tin imported from Portugal only one-third of the costs stemming from mining German tin ores. BArch, R 121/1455, Lohmann & Co to Roges, 11 Dec. 1941; R 3101/30413, fo. 31, Zwitterstock-Aktiengesellschaft, Altenberg/Erzgeb.

164. See the plans in BArch, R 3101/30410, and R 3101/30491.

165. BGR-Archiv, /0059780, 'Forschungsergebnisse bei Bodenschätzen, in denen eine besondere Mangellage herrscht', 1942.

166. BGR-Archiv, /0059988, Reichsamt für Bodenforschung, Zweigstelle Freiberg, 'Bericht über die derzeit mögliche Zinn-Wolfram-Produktion', 14 Jan. 1943.

half of 1944, was a massive capacity expansion of the German tungsten mines ordered. Within a year, total German tungsten production was supposed to increase to 1,200 tons, covering two-thirds of Germany's consumption needs.[167] Combined with the still-existing stocks, German tungsten consumption could have been met up to 1948.[168]

The nickel mining and refining policy was quite similar. As in the case of tungsten, standby capacities were built up, and the mining output was, as originally scheduled, only slowly increased up to mid-1944.[169] In addition, the expansion of standby refineries and the exploration of new mines continued.[170] A faster increase of nickel mining was not necessary because Germany had prospective access to the rich Finnish nickel mines in Petsamo from the summer of 1940.[171] Nevertheless, in 1943, when the Finnish supply peaked, the war administration prepared a further expansion of the standby capacities; under this scheme the annual German nickel output of 1,100 tons (covering about 15 per cent of Germany's consumption needs in 1943) could have been doubled immediately and quadrupled by 1946.[172] To this end only about an additional hundred workers would have been needed.[173] In the spring of 1944, 1.5 million tons of nickel ores with a metal content of 14,000 tons were prepared for mining. Once Germany was cut off from her main nickel supply source in Finland in the summer of 1944, the German war administration accelerated the programme described above and quadrupled the monthly German nickel production between July and October 1944. The plan was to raise German nickel production further to 5,000 tons annually until late 1945; German ores would then have covered 75 per cent of domestic consumption. Combined with the still-existing stocks, German nickel consumption could have been met up to 1948.[174]

167. BArch, R 3101/30393, fo. 10, 'Roherzdurchsatz und Metallerzeugung im Konzentrat', 1 Apr.–30 Sept. 1944; fos 31–2, 'Betrieb Zinnwald'. BArch, R 3101/30865, fo. 295, Reichswirtschaftsminister to Reichsminister der Finanzen, 23 Nov. 1944. Note that, in terms of workforce, this increase required only about 1,000 additional workers. BArch, R 3/1957, fo. 234, '20. Wochenbericht des Planungsamtes', 30 May 1944.

168. For consumption and stocks, see BArch, R 3/576. Tungsten content in German soil added up to 6,247 tons at the end of the war: HA Krupp, WA 142/2778, 'Übersicht über die Wolfram und Molybdänproduktion im Erzgebirge und im Kaiserwald'.

169. See BArch, RW 19/335, fo. 477, Wochenbericht, 10–16 Sept. 1939, and the documents in BArch, R 3101/30491.

170. See, for example, HA Krupp, WA 41/4-216, Krupp Abteilung Schlesische Nickelwerke to Krupp, Essen, 6 Apr. 1940; WA 142/2880, Spangenberg to Krupp AG, 21 Nov. 1942.

171. P.T. Sandvik and J. Scherner, 'Why did Germany not Fully Exploit the Norwegian Nickel Industry, 1940–45?', in Frøland, Ingulstad and Scherner, eds, *Industrial Collaboration*, pp. 275–300.

172. BArch, R 3101/30339, fo. 25, note, 6 Dec. 1943.

173. For the following, see BArch, R 3101/30865, fo. 18, Fachgruppe Metallerzbergbau der Wirtschaftsgruppe Bergbau to Reichsminister für Rüstung und Kriegsproduktion, 29 Mar. 1944; fos 45–6, Reichswirtschaftsminister, note, 14 Sept. 1944; fo. 88, 'Bericht über die Nickelerzeugung der Erzlagerstätte Krems', 26 Sept. 1944. BArch, R 3101/31093, fo. 376, 'Metallerzförderung in der zweiten Hälfte des Jahres 1944', 9 Feb. 1945.

174. HA Krupp, WA 142/2778, note, 13 Dec. 1944; 'Vermerk über die 2. Sitzung des Arbeitskreises für Stahllegierungsmetalle am 17.11.1944'.

It has been claimed that the increase of mining output started too late, that is, only at the end of the war.[175] The implicit assumption of this claim is that an earlier expansion of German mining production would have made metal allocation cuts, such as those implemented for nickel and tungsten, unnecessary. No doubt such cuts did take place, and in some instances—but certainly not always—negatively affected the quality and output of German armaments. For example, scholars note that in summer 1943 armour-piercing ammunition production was suspended in order to conserve tungsten.[176] In the same year, the Luftwaffe complained about nickel allocations being too short.[177] Yet, considering the size of German stocks at the time, it seems that allocation cuts were dictated neither by an actual metal shortage nor by a delayed expansion of German mining.[178] In the case of armour-piercing ammunition, a continuation of production from mid-1943 to mid-1944 would have required only 360 tons of tungsten, leaving Germany with some stocks (about 1,200 tons) once it began to use its tungsten standby capacities.[179] With regard to the Luftwaffe, too, there is no indication that the actual nickel allocation was dictated by a metal shortage or by a delayed expansion of German mining.[180] In 1943, German nickel stocks were more than 8,000 tons—not much lower than in September 1939. Stocks even slightly increased during the next twelve months. The additional quantity demanded by the Luftwaffe in 1943 cannot have been large—certainly significantly lower than the average nickel consumption of the Luftwaffe during the first three years of the war (around 150 tons per month).[181] Anyway, the actual amount of allocation cannot be explained by a real shortage of nickel, especially when considering the German mining potential. This is confirmed by the fact that, in the case of nickel from 1943 onwards (as in the case of copper and tin), the relative share of metals allocated to the companies which was not called up by them increased.[182]

175. See Jäger, *Die wirtschaftliche Abhängigkeit*, pp. 84–7, 91–4.

176. L. Caruana and H. Rockoff, 'A Wolfram in Sheep's Clothing: Economic Warfare in Spain, 1940–1944', *Journal of Economic History*, lxiii (2003), pp. 100–126, at 118. Note that, at the point when the production of armour-piercing ammunition was stopped, Germany disposed of very high stocks of this ammunition, amounting to be at least 10 months' worth of production as in the first half of 1943 (in tungsten content). BArch, R 3101/30491, fo. 32, 'Wolfram-Planung', 1 Oct. 1944.

177. Jäger, *Die wirtschaftliche Abhängigkeit*, p. 242. On the impact of the supply situation on the production programme of the Luftwaffe, see H. Giffard, 'Engines of Desperation: Jet Engines, Production and New Weapons in the Third Reich', *Journal of Contemporary History*, xlviii (2013), pp. 821–44.

178. For German metal stocks, see BArch, R 3/576.

179. This assumption is based on the allocation for armour-piercing ammunition in the first half of 1943: BArch, RH 8/1042, OKH to OKW, 'Fertigung von Hartkernmunition'.

180. According to Speer, the complaint of the Luftwaffe was not justified and served to draw attention from delays caused by the Luftwaffe to the production process: Jäger, *Die wirtschaftliche Abhängigkeit*, p. 242.

181. BArch, RW 19/2336, fo. 8.

182. BArch, R 3/576, 'Zinn, Kupfer, Nickel'.

In other words, there is little indication that decisions to cut allocations during the second half of the war owed much to an immediate or a medium-term shortage; rather, they were the result of an allocation and stockpiling policy which aimed to stretch out Germany's capacity to wage war under blockade conditions. From 1943 on, the goal of the German tungsten policy was, as the annual plan for 1943 reveals, the expansion of the German stock.[183] This stockpiling policy is also confirmed by the decision to continue the very expensive—in terms of workforce required—metal mobilisation measures for copper and tin beyond late 1942, despite the fact that both tin and copper stocks were at this point far bigger than at the beginning of the war.[184] This policy was mainly responsible for the fact that by November 1944 German stocks actually exceeded those in September 1939 by 135 per cent (copper) and 150 per cent (tin). This stockpiling policy, expressed in allocation cuts in the case of tungsten and continued metal mobilisation in the cases of copper and tin, probably resulted from the fact that Germany's strategic outlook had become bleak in the eyes of Albert Speer and the leading Nazis in 1943: from this point on, Germany had to wait for mistakes to be made by the enemy in order to win the war.[185] Indeed, whereas the time horizon of German supply plans in the early stage of the war had a duration of three years, 1943 plans had a five-year coverage.

V

In contrast to what has been argued by scholars, the German economic administration actually carried out ample war preparations in the field of non-ferrous metals that were based on the lessons of the Great War, which it had carefully and covertly studied. Given these preparations and considerations, which suggest that Hitler did indeed prepare for a major war, and not for a series of short wars, Germany could expect to sustain a longer war (as long as the Great War) even in the case of a sea blockade. Such a war could not have been endless, of course, but certainly far longer than previously thought. Germany´s comparatively low metal stocks, combined with high peacetime import dependency, are therefore neither evidence that Hitler did not intend to wage a longer war, nor that the country was not prepared for such a conflict because the war came prematurely or because German pre-war economic administration was incompetent. This article thus refutes one fundamental assumption of the Western powers' long-war strategy and casts doubt on the conventional wisdom regarding the alleged unpreparedness of Germany for a longer war. To be sure, further sectors that are commonly believed to be weak points of German war

183. BArch, R 3/576, 'Wolfram'.
184. Scherner, 'Lernen und Lernversagen'.
185. Schlie, *Albert Speer*, pp. 434–5.

preparedness must also be critically re-examined before we can draw general conclusions about Germany's war preparation and the extent of Hitler's gamble in 1939.

What is clear is that not only historians but also the contemporary intelligence services of the Western powers misjudged Germany's ability to master the problems of metal supply under a blockade. This misjudgement can be partly attributed to the secretiveness of the Third Reich, which made it difficult to assess the effects of Germany's pre-war policy. In addition, due to German deception during the inter-war period, the effectiveness of the measures implemented by Imperial Germany during the Great War to overcome the blockade was little known outside Germany. This may explain why the IIC tended to overestimate the effects of the blockade during the Great War.[186] Yet, seeing that some quantitative information had been published in Germany immediately after the Great War, which suggested, for instance, the massive effects of substitution and conservation during that conflict,[187] the expectations of the Western powers in the late 1930s were at the least overly optimistic.[188] In hindsight, the assessment of Archibald Bell, a well-informed contemporary critic of blockade optimism, proved correct. Bell, who authored the official British history of the blockade during the Great War in 1937, did not believe (given the experience of the last war) that a future blockade would have a decisive effect, especially with regard to metals.[189]

What the German planners had learned from the metal policy of the Great War—especially with regard to the significance of substitution and conservation measures—proved, as the statistics compiled in this article clearly show, to be far more crucial for the German 'metal miracle' during the Second World War than the ruthless plundering of occupied countries' metal stocks. In this way, Germany's most important hidden reserve in the field of metals was its scientists: they analysed and categorised their wartime experiences, they carried out substitution research, they tested new production methods, they invested in substitutes, and they modified the construction of manufactures, all in order to reduce consumption. In the cases where shortages existed during the war they were not a result of an actual imminent lack of metals; rather it seems that during the second half of the war they stemmed from the expanding time horizon of the

186. On this overestimate, see W.N. Medlicott, *The Economic Blockade*, II (London, 1959), p. 634; G. Till, 'Naval Blockade and Economic Warfare in the European War, 1939–45', in B.A. Elleman and S.C.M. Paine, eds, *Naval Blockades and Seapower: Strategies and Counter-Strategies, 1805–2005* (London, 2006), pp. 117–30, at 117.

187. See, for example, Tröger, 'Technik in der Metallwirtschaft', p. 524.

188. The British treasury, however, was very sceptical. See, for example, Hinsley, *British Intelligence*, p. 70; Overy, *War and Economy*, p. 213. After the war had started, the Western powers soon began to second-guess the prospects of a 'long-war strategy', and thus the blockade. T. Imlay, *Facing the Second World War: Strategy, Politics and Economics in Britain and France, 1938–1940* (Oxford, 2003), pp. 7–9, 54–60, 73–7, 123.

189. A.C. Bell, *Sea Power and the Next War* (London, 1938), pp. 147–50.

Nazi regime regarding the end of the war, which was a consequence of Germany's bleak strategic outlook. In short, the German defeat was not the result of a lack of preparation in the 1930s but of the strategic decision to start a war which, as Hitler well knew,[190] ran the danger of drawing in an ever more superior coalition of enemies the longer the war lasted. Indeed, if it had been only for non-ferrous metals, Germany could have continued the war for a few more years.

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190. Ullrich, *Hitler*, pp. 88, 101–2.

Appendix

Table A1: Determinants of German metal supply in a future war (metric tons)

	(I) Monthly allocation at the beginnings of the war[a]	(II) Expected monthly consumption in 1940[b]	(III) Supply by domestic scrap[c]	(IV) Expected monthly imports[d]	(V) Monthly net consumption to be covered domestically[e]	(VI) Stocks[f]	(VII) Metal mobilisation potential[g]	(VIII) Annual mining output for a 3-years-war[h]	(IX) Annual mining output for a 4-years-war[h]	(X) Annual mining output in 1939[i]	(XI) German ore reserves[j]
Copper	22,000	20,000	6,400	6,667	6,933	194,000	270,000	0	0	23,502	1,774,000
Tin	612	562	236	11	315	7,845	>5,281	0	499	311	47,500
Nickel	807	707	71	343	293	10,885	3,120	0	0	527	40,000
Tungsten	277	249	0	0	249	5,506	0	1,153	*1,612*	59	5,800

Sources:

[a]BArch, RW 19/2336. For tungsten, data from the first quarter of 1940 is used because, as this document reveals, no rationing of most steel alloys took place during the last quarter of 1939.

[b]For tin, nickel, and copper, see BArch, RW 19/351, Wehrwirtschaftsamt, 4 Nov. 1939; for tungsten, see BArch, RW 19/335, fo. 184, 'Wochenbericht der Rohstoffabteilung, 12.-8.11.1939'.

[c]Calculated by employing the expected annual average recycling quota in % of consumption as reported in BArch, RW 19/2346, 'Zahlen-Zusammenstellung zur Beurteilung der Rohstofflage bei einer längeren Kriegsdauer'.

[d]For tin, copper and nickel: BArch, R 3102/3057, RwP to AA, 9 Oct. 1939, and Reichsamt für wirtschaftliche Statistik und Planung to AA, 3 Nov. 1939. No tungsten had been imported from the respective countries in 1938.

[e](V) Obtained by subtracting the sum of (III) and (IV) from (II).

Table A1: Continued

[f]BArch, R 3/1797, 'Statistische Schnellberichte'.

[g]See text. For nickel, see Jäger, *Abhängigkeit*, p. 224; for copper, see BArch, RH 61/1125, 'Die Kriegsbewirtschaftung der Metalle, 1. August 1914 bis 31. August 1916'; for tin, see BArch, RH 61/695, 'Metallmobilisierung'; BArch, RH 61/869, 'Immobile Vorräte', 28 Mar. 1917.

[h]In a first step I multiply (V) by the factor 36 (= 3 years) respectively by the factor 48. In a second step I subtract from this amount the sum of (VI) and (VII). By dividing the difference from this procedure by the factor 3 respectively 4, (VIII) respectively (IX) results.

[i]BArch, R 3101/31014, fo. 60, 'Kriegsaufgaben des Metallerzbergbaus für die Jahre 1940 bis 1942'.

[j]For copper, I added up the estimated metal content of the newly discovered fields in Lower Silesia in 1938 (BArch, R 3101/15421, fo. 86, 'Bericht über die bis 30.6.1938 durchgeführten Untersuchungsarbeiten zur Aufschliessung, Gewinnung und Aufarbeitung des niederschlesischen Kupfermergels') and the ore estimate in 1934 which did not include the Lower Silesian fields (BGR-Archiv/20111134, 'Die Beteiligung deutscher Kupferzlagerstätten an der deutschen Kupferversorgung ca. 1934', Dr Ernst Fulda, Bergrat an der Preussischen Geologischen Landesanstalt in Berlin). Seeing that the German copper mining between 1934 and 1939 amounted to about 100.00 tons (metal content), this amount was subtracted. For tin, I added up the estimated metal content of the respective mines in Germany (BArch, R 8135/7925, 'Niederschrift über die Besprechung vom 20. Dezember 1939 die Ausbauvorhaben der Sachsenerz Bergwerksgesellschaft betreffend'; BArch, R 2/15440, fos 48–51, Reichs- und Preussische Wirtschaftsminister to Reichsminister der Finanzen, 11 June 1936) and estimated the metal content in Sudetenland on the basis of the annual expected mining and the amortisation period (BArch, R 43II/1496a, fos 144–5, Fritz Geisler to Reichsminister Lammers, 7 July 1938). The same procedure is applied in the case of tungsten (BArch, R 8135/7925, 'Niederschrift über die Besprechung vom 20. Dezember 1939 die Ausbauvorhaben der Sachsenerz Bergwerksgesellschaft betreffend'; HA Krupp, WA 142/928, 'Aktenvermerk über die Befahrung der Gewerkschaft "Vereinigung", Pechtelsgrün, Vogtland'; BArch, R 43II/1496a, fos 144–5, Fritz Geisler to Reichsminister Lammers, 7 July 1938). For Nickel, see HA Krupp, WA 41/4-216, Krupp Abteilung Schlesische Nickelwerke to Krupp, Essen, 6 Apr. 1940, which refers to ore reserves as known shortly before the outbreak of the war.

Table A2: Substitution of copper and tin in armament production, 1938/9–43

	Copper-steel ratio(in %)		Tin-steel ratio(in %)
	Ammunition	*W & E*	*W & E*
1938/9	4.00	2.14	0.120
1940/I	2.40	1.70	0.035
1940/II	n.a.	n.a.	n.a.
1940/III	n.a.	n.a.	n.a.
1940/IV	n.a.	n.a.	n.a.
1941/I	1.30	1.30	0.055
1941/II	1.76	1.30	0.047
1941/III	1.23	1.13	0.036
1941/IV	0.70	0.86	0.047
1942/I	0.21	0.73	0.036
1942/II	0.24	0.48	0.027
1942/III	n.a.	n.a.	n.a.
1942/IV	0.18	0.40	0.019
1943/I	0.15	0.40	0.018
1943/II	0.13	0.22	0.013

Note: Data for 1938/9, which cover the period between 1 April 1938 and 31 March 1939, rely on requests whereas all other data rely on allocation.

Sources: 1938/9: author's calculation based on BArch, RH 15/150, 'Bedarf der Wehrmacht an Eisen und Stahl und unedlen Metallen im Haushaltsjahr 1938/9, t/Monat'; for 1940/I, own calculation based on BArch, RH 8/12, 'Aufstellung über den Einsatz des Eisen- und Stahlkontingents sowie der wichtigsten NE-Metallkontingente OKH (ohne Schnellplan) im I/40 in moto', 8 Feb. 1940; for 1941/I, own calculation based on BArch, RH 8/1424; for 1941/II–1942/ II, see BArch, RH 8/12, 'Relation zwischen Eisen und Stahl und den Stahlleg. bzw. NE-Metallen bei den Zuteilungen, Eisen und Stahl=100', 6 July 1942; for 1942/ IV, 1943/I and 1943/II, own calculation based on data provided in BArch, RH 8/12, 'Kontingente IV/42', 'Kontingente I/43', and 'Kontingente II/43'.