

**THE DEFENCE INDUSTRY AS AN EXPLANATORY FACTOR OF THE GERMAN  
DEFEAT DURING  
WORLD WAR I: LESSONS FOR FUTURE CONFLICTS**

**Dr. Ioannis-Dionysios Salavrakos,**

(European Parliament, Belgium) (\*)

---

**ABSTRACT:** *The failure of the German war machine during WWI is attributed mainly to the wrong decisions which the German High Command made throughout the war. According to the mainstream literature the defeat of the Marne in the autumn of 1914 has been the first error in a chain of errors, which the Germans made during the four year conflict. However, although the above criticism is correct it is incomplete. Throughout the war years there was an immense shift of economic resources from the civil sector of the economy to the military sector of the economy. The problem is that there was not an optimum use of these resources. The paper has to address three main issues: The first is associated with the quantity of the defence production, which although it was the biggest across all belligerents, it was a hidden story of failure rather than success, since a waste of resources in the production process occurred. The German defence industry was an immense oligopoly, which practically throughout the war, acted either as a monopoly or a cartel. Thus a small number of firms were able to set prices, production levels and qualitative characteristics. In order to maximise their own profit the above companies ignored the military bureaucracy and even the politicians. Thus defence production could have been higher, if there was some competition in the economy. The second point of the paper is associated with the quality of the defence equipment, which was not superior, when compared to that of the allied defence industries. Thus with limited exemptions the German weapons were not superior to the Allied ones. The third point demonstrates that the Allies and especially the UK and the USA (which after all had immense resources compared to the Central Powers) had used them slightly better compared to the Germans. We realise that even nowadays the defence industry across the globe is a monopoly or an oligopoly. Obviously not many firms produce defence articles across states. However the more they are the better it is because in case of wars (as the experience of WWI has demonstrated) a handful of companies can make societies as well as political / military bureaucracies “prisoners” by imposing their own plans.*

**KEYWORDS:** Economic History, Total War

**JEL Classification:** N44, H56

---

## **INTRODUCTION**

The intellectual aspiration of the current research paper is to address three main issues: The first is associated with the quantity of the defence production. It is true that the German war production in terms of defence articles was the biggest across all belligerents. However behind the impressive statistics which *prima facie* outperform the Allied effort lays a hidden story of failure rather than success. The failure assertion is documented by examining the

German defence industry under the light of modern economic theory. The German defence industry was an immense oligopoly, which practically throughout the war, acted as a monopoly. The main industries in the sector were “Krupp”, “Thyssen”, “Deutsche Waffen und Munitionsfabriken AG”, “Mauser” and “Rheinmetall”. All five were producing guns, grenades, shells, submarines, rifles, machine-guns, surface ships. Three more enterprises (“BASF”, “Bayer”, “Hoest”) were producing explosives, chemicals and even “ersatz” (=substitute) products. In the field of telecommunications equipment two companies dominated the industry (“AEG” and “Siemens”). The optical equipment (binoculars, viewfinders, etc) was practically dominated by a single firm (“Zeiss”). All the other enterprises across these and other related and supporting industries had an auxiliary and limited role to play. Thus we argue that although German production was higher from that of Allied countries practically there is a complete absence of economies of scale and scope. Thus because defence production was practically under the control of a small number of enterprises, they were able to act as a “cartel” and thus transforming the oligopoly to a monopoly they were able to set prices, production levels and qualitative characteristics. In order to maximise their own profit the above companies ignored the military bureaucracy and even the politicians. Thus defence production could have been higher, if some competition was introduced in the economy.

The second point of the paper is associated with the quality of the defence equipment, which was not superior, when compared to that of the allied defence industries. Thus with limited exemptions the German weapons were not superior to the Allied ones. In other words the German defence industry failed to produce technologically advanced weapons which could have made the difference on the battlefields of the various fronts.

The third point attempts to analyse the German defence industry viz. a viz. the industry of the other belligerents. Thus the other belligerents have also used a small number of industries in order to supply them with the necessary defence articles. Across belligerents, however, the country which partially adopted the doctrine of perfect competition was the UK. The UK also used the industries of India and the USA for its own defence-industrial mobilisation, by subcontracting. Thus the Allies (which after all had immense resources compared to those of the Central Powers) had used them better compared to the Germans.

We realise that even nowadays the defence industry across the globe is a monopoly or an oligopoly. Obviously not many firms produce defence articles across states. However the more they are the better it is because in case of wars (as the experience of WWI has demonstrated) a handful of companies can create societies as well as political / military bureaucracies “prisoners” by imposing their own plans. The article has the following structure: In the first section we provide an overview of defence industries during the 1870-1913 period. The second section provides an analysis of the military-industrial mobilisation during the war years (1914-1918). The third section compares and contrasts the German defence production with that of the other belligerent countries. The final section summarises the main points and provides an assertion which relates the defence industry of the First World War with the current evolutions in the industry and its role in current conflicts.

**THE BIRTH OF THE MODERN GERMAN DEFENCE INDUSTRY: THE 1870-1913 PERIODS.**

The German defence industry has been quite important for the Second Reich. It was split between private and state owned manufactures. Furthermore, a number of private companies had a dual purpose character, producing for the civil as well as the military sector of the economy.

The first private company, which was the epitome of German industrial muscle was Krupp. Located in Essen the firm increased its buildings by 2.1 hectares annually during the 1903-1906 period, and by 2.6 hectares during the 1906-1914 period. The company employed 81,000 workers in 1914 and the company's annual electricity consumption was equal to that of the town of Berlin. Some machine tools weighted 8,000 tons each and for the transportation of raw materials, semi-finished goods and final products the company was using as many wagons and trains as they were needed between Frankfurt and Munich.<sup>1</sup>

However, a big portion of the company's production was not for the military sector of the economy. During the year 1913-14 only 54% of the company's production was oriented on various defence articles, and an additional 11% was concerning ship armour. The rest of the production was for the civil sector of the economy (steel, iron, railways, shipping-yards). Furthermore the company had an extrovert strategy, targeting mainly international markets, rather than the market of the Reich. By the end of the 19<sup>th</sup> century the 86.4% of total production was exported. This percentage was reduced during the 1900-1913 period and by 1914 the exports absorbed the 51% of production. Until that time the company had exported 26,000 artillery pieces in 52 countries. Major foreign markets were those of Belgium, Austria-Hungary, Ottoman Empire and Italy.<sup>2</sup>

Concerning the domestic market the Navy was a better client rather than the army. To illustrate, during the 1910-1914 period the army absorbs 12.8% of the ammunition, when the navy absorbed the 43.3% of the company's production.<sup>3</sup> One of the most profitable investments of the company was the Bertha gun which guaranteed an investment return of 10% in 1911. This was increased to 12% in 1912 and to 14% in 1913.<sup>4</sup>

The second most important defence producer was the Rheinischen Metallwaren und Maschinenfabrik, known as Rheinmetall. The company's headquarters was in Dusseldorf, and it was set up in 1899. By 1914, under the management of Heinrich Erhardt the company had a labour force of 8,000 workers and could manufacture high velocity artillery, as well as shells, the latter were introduced in the German army from 1905. The company exported to various countries such as Great Britain, Russia, Austria-Hungary, Norway.

---

<sup>1</sup> See: 1) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 1,031, 2) David Stevenson: "Armaments and the Coming of War. Europe 1904-1914", Oxford, Clarendon Press, first edition, 2000, page 18, 3) William Manchester: "The Arms of Krupp", Back Bay books, London 2003, 4) Lothar Gall: "Krupp im 20. Jahrhundert", Siedler Verlag, Berlin, 2002.

<sup>2</sup> See: D. Held & A. McGrew & D. Goldblatt & J. Perraton: "Global Transformations. Politics, Economics and Culture", Polity Press, 2000, pages 108-109.

<sup>3</sup> See: David Stevenson: "Armaments and the Coming of War. Europe 1904-1914", Oxford, Clarendon Press, first edition, 2000, page 25.

<sup>4</sup> See: William Manchester: "The Arms of Krupp", Back Bay books, London 2003, pages 263 and 282.

The major small arms manufacturer was the DWMF (Deutsche Waffen und Munitions Fabriken). The company was established in 1896 and was based in Berlin. The DWMF was the outcome of a merger of four enterprises: 1) The Deutsche Metallpatronenfabrik AG based in Karlsruhe, 2) The “Ludwig Loewe”, 3) The Rottweil-Hamburg Powder Co. based in Rottweil and 4) The Rheinisch-Westfaelischen Powder Co. based in Cologne. Until 1914 part of the DWMF was also participating in the Osterreichische Waffensfabrik-Gesellschaft. Initially the company was producing under license British equipment of Vickers and Maxim companies. However after a collaboration agreement with Odendorf based company Mauser the company produced the M1904 rifle. Between, 1890-1912 the German companies produced 655,000 rifles for the German army and exported an additional number of 2,922,000.<sup>5</sup> Other private companies existed in shell and explosives manufacturing. One of them was the British-German joint venture “General-Pooling Arrangement”, while optical equipment (binoculars etc) was provided from “Zeiss” company. Apart from the private companies the armed forces had their own factories, most of them in Spandau, which produced small arms, ammunition, uniforms, even canned food and fresh bread.<sup>6</sup>

Turning to shipyards there was a similar situation with private and state owned shipyards. There were three state shipyards (one in Danzig, in Kiel and in Wilhelmshaven). The Danzig shipyards, during the 1889-1908 period, constructed nine cruisers and a number of smaller ships. The Kiel ones, during the 1877-1914 period, constructed 17 warships and in Wilhelmshaven during the 1878-1914 period 14 warships were constructed. The number of private shipyards was higher. There were 15 shipyards which constructed a huge number of ships. These were as follows:

1. The Blohm & Voss shipyards; during the 1892-1914 period constructed 10 ships
2. The Vulkan Hamburg shipyards which were producing exclusively ships for the commercial navy during the 1909-1914 period.
3. The Stulcken shipyards with unknown production
4. The AG Weser shipyards which produced 43 warships during the 1873-1913 period
5. The Bremen Vulkan shipyards with unknown production level
6. The Seebeck shipyards with unknown production level.
7. The Tecklenborg shipyards producing exclusively for commercial fleet
8. The Nordseewerke Emden Wert und Dock AG with unknown production level
9. The Kiel-Flensburg shipyards with unknown production level
10. The Krupp-Germania shipyards, part of the Krupp company. They were bought by
11. Krupp’s in 1882 and from 1890 they were producing armour for ships. During the 1890-1914 period they produced 21 big warships, 54 torpedo boats and the first submarine for the navy in 1906.
12. The Howaldtswerke Kiel shipyards, with significant but unknown production.
13. The Flensburg-Schifbau AG shipyards with unknown production.
14. The Vulkan Stettin shipyards which during the 1876-1913 period built 31 warships
15. The Schibau Elbing shipyards which were concentrated in the production of torpedo boats for the German navy as well as for other navies. During the 1884-1899 period they constructed 110 torpedo boats, whereas during the 1900-1914 period an additional number of 90 torpedo boats was produced.

<sup>5</sup> See: Martin Kitchen: “A Military History of Germany”, The Citadel Press, 1976, page 170.

<sup>6</sup> See: David Stevenson: “Armaments and the Coming of War. Europe 1904-1914”, Oxford, Clarendon Press, first edition, 2000, page 19.

16. The Schichau Danzig shipyards during the 1896-1913 period constructed 9 large warships.<sup>7</sup>

Turning to aviation industry the main aeroplane producers were as follows: Albatros, Automobil und Aviatic AG, Dornier, Fokker (the German part), Halberstadt, Hansa-Brandenburg, AEG, Siemens,-Schuckert Werke, Zeppelin Werke Staaken.<sup>8</sup>

Finally one has to mention the dual purpose industries which could produce for both the civil as well as military sector of the economy. Table 1 lists most of them. The data about the German defence industry are scant.<sup>9</sup> However, the structure of the industry was similar to that of other European countries. There were some leading manufactures which controlled most of the domestic market and also had a dominant presence in the international market. These were followed by a considerable number of other smaller firms with limited presence in the domestic market and with minor international presence. Unfortunately only limited economic data exist, related to the activities of these enterprises.

**Table 1: Dual Purpose Industries in the Second Reich (according to the level of assets in 1913)**

Enterprise	Year of establishment	Industrial sector	Assets in m. M in 1913
Krupp	1812	Coal/Steel/ Machinery	587,2
Thyssen	1871	Coal/Steel/ Machinery	504,2
AEG	1883	Electrical	462,8
GBAG	1873	Coal	394,9
Siemens-Schuckert	1903	Electrical	313,6
Deutsch-Luxembourg	1901	Coal / Steel	278,2
Thyssen GDK	1891	Coal / Steel	249,9
Phoenix	1851	Coal/Steel/ Metallurgy	223,9
Siemens & Halske	1847	Electrical	187,3
Harpener Bergbau	1856	Coal	185,9
Hohenlohe	1905	Coal	134,0
Hibernia	1873	Coal	131,9
GHH (Haniel)	1810	Coal/Steel/ Machinery	130,4
Bayer	1881	Chemical	127,5
BASF	1865	Chemical	126,3
Loth. Huettenverein	1897	Coal / Steel	116,0
F & G Carlswerk	1900	Metallurgy	114,8
Mannesmann	1890	Steel/	114,7

<sup>7</sup> See: R.J Winklareth: "Naval Shipbuilders of the World", Chatham Publishing, London, 2000, pages: 243-273.

<sup>8</sup> The German aviation industry and the types of aeroplanes that produced is analysed in R. Jackson: "The Encyclopedia of Military Aircraft", Paragon editions, 2002.

<sup>9</sup> Financial data on some German defence industries exist in the following: For Krupp see: Michael Epkenhans: "The German Armament Industry and Economic Development, 1870-1914", paper presented in the Workshop: "The Armament Industry and European Economic Development (1870s-1939)", European University Institute, Florence, Italy.

		Metallurgy	
Hoechst	1880	Chemical	114,3
Deutsche Solvay	1885	Chemical	112,7
MAN	1898	Mechanical construction	112,3
Rombach	1884	Coal / Steel	111,5
Mansfeld	1851		110,4
Bergmann	1900	Electrical	103,9

**Sources:** 1) J. Fear: "German Capitalism", in Th. K. McCraw (ed.): "Creating Modern Capitalism", Harvard University Press, 1997, page 145, 2) David Stevenson: "Armaments and the Coming of War. Europe 1904-1914", Oxford, Clarendon Press, first edition, 2000, pages 15-26.

### **INDUSTRIAL PRODUCTION DURING THE WAR YEARS (1914-1918): A LITERATURE ANTHOLOGY**

The German defence industry outperformed all other industries from the rest belligerent countries. The data are scant however the levels of production can be re-enacted. We shall impose a dichotomy analyzing developments until 1916 and then in the 1917-1918 period.

#### **The evolution of raw material production and inputs for the defence industry.**

For the production of war material raw materials such as steel, iron, pig-iron, coal and oil were needed. The supply of raw material deteriorated during the war years creating quite important bottlenecks to the industry. Tables 2, 3 demonstrate the evolution of supplies of raw materials.

**Table 2: German Industrial Production 1913-1918 (in m. tons)**

	1913	1914	1915	1916	1917	1918
<b>Coal</b>	277,3	245,3	234,8	253,3	263,2	258,2
<b>Pig-iron</b>	28,6 (16,7)	20,5 (12,4)	17,7 (10,1)	21,3 (11,3)	22,5 (11,6)	18,4 (10,6)
<b>Steel</b>	17,6	13,8	12,3	14,9	15,5	14,1
<b>Iron</b>	28,608	25,505	17,710	21,334	22,465	18,392

**Sources:** 1) John Ellis & Michael Cox: "The World War I Databook", Aurum Press London, 2001, pages: 285-286, 2) Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume II (1916-1921), Facts on File, 1991, pages: 294-295. [Indexes of industrial production can be found in Gerald Feldman: The Great Disorder. Politics, Economics and Society in the German Inflation 1914-1924, Oxford, 1997, page 78].

The data of Table 2 demonstrate the problematic evolution of the supply of raw materials. The supply situation was extremely critical during the last year of the war when the German army had made its final titanic effort to defeat the Allies before the arrival of US troops en masse in the Western front. Unfortunately there are very limited data on the exact amount of raw materials needed in defence industry. Thus we do not know the exact quantities of iron and steel needed for the production of a heavy gun, or a light howitzer or a machine gun. However the supply situation was critical and rapidly deteriorating throughout the war. Turning to the production / consumption of oil this is presented in Table 3.

**Table 3: Oil Consumption / production in Imperial Germany (1914-1918) in thousand tons**

	<b>1914 June-Dec</b>	<b>1915</b>	<b>1916</b>	<b>1917</b>	<b>1918</b>	<b>Total</b>
Extraction	45	99	93	91	89	<b>417</b>
Reserves 1-8-1914	343	-	-	-	-	<b>343</b>
Imports	191	353	732	750	705	<b>2,731</b>
Exports	3	-	1	10	20	<b>34</b>
War captured	30	Minimal	minimal	40	100	<b>170</b>
Ersatz	20	200	320	450	500	<b>1,490</b>
Quantities after economising	10	50	70	90	100	<b>320</b>
Reserves End 1918						<b>150</b>
Consumption	290	700	1,210	1,410	1,470	<b>5,290</b>

**Source:** Rainer Karlsch & Raymond G. Stokes: "FAKTOR ÖL. Die Mineralölwirtschaft in Deutschland 1859-1974", Verlag C.H. Beck, Munich 2003, page 99.

Turning to Table 3 we can certainly demonstrate the crisis in transportation as well as other related industries (refineries, oil by products such as lubricants and paraffine etc). It is obvious that total oil demand during the war reached the amount of 5,290,000 tons which was covered by 98.2%. However the crisis in the related industries affected indirectly the war effort. In spite of the critical supply situation the production of defence industries increased throughout the war years. The following sections demonstrate this point.

### **Small arms and ammunition (1914-1916)**

The monthly rifle production in August 1914 was just 3,600 pieces. However, there were huge stocks across various arm manufacturers, sporting associations, etc. To illustrate, only in 1911 one German company had a stockpile of 292,000 rifles (250,000 Austrian manufacturing and 42,000 of Italian). These types of weapons, as well as those which were captured in the various battlefields, were called "Beutegewehr" (=war booty) in the German terminology. However the monthly rifle production by 1916 was increased to 250,000 pieces.<sup>10</sup>

During the 1870-1871 war the German army was supplying every soldier with 200 bullets and the average consumption was lower, just 56 bullets per soldier. In 1914 the number of bullets per soldier was increased to 280 and during the first weeks the whole amount was consumed. The total amount of infantry ammunition produced during the August-December 1914 period was 725,000,000 cartridges and during the period January-December 1915 reached the level of 2,200,000,000 cartridges.<sup>11</sup>

<sup>10</sup> See: Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, page 263, 2) John Walter: "The Greenhill Dictionary of Guns and Gunmakers", Greenhill Books, 2001, page 71.

<sup>11</sup> See: Mark Osborne Humphries & John Maker (eds.): "Germany's Western Front 1915", Wilfrid Laurier University Press, 2010, page 383.

Turning to machine gun production a considerable increase occurred during the 1914-1915 period. In August 1914 there were 2,450 machine gun pieces and by 1915 were increased to 8,000. The monthly production during that year increased from the level of 200 to 600 pieces. The total machine-gun production for the 1915-1916 period (fiscal year) was 3,950 pieces.<sup>12</sup> Gradually but steadily production increased, across all types of small arms and ammunition. To illustrate only the production of one German firm (DWMF) at the beginning of April 1915 was 1,400 Mauser type rifles, 700 Parabellum pistols, 10 machine-guns, 2 million bullets, 10,000 grenades, 5,000 detonators per day.<sup>13</sup> To illustrate, in 30<sup>th</sup> June 1915 when a German brigade attacked a 2 km front in the French region of Bagatelle it had at its disposal 36,000 hand grenades!<sup>14</sup> Further increases occurred in 1916, during the great battles of Verdun, Somme and the Eastern campaign. According to one source the monthly machine gun production was 2,300 pieces throughout that year.<sup>15</sup> By the middle of 1916 60m cubic yards of soil were excavated and in weekly basis in July 1916 7,000 tons of barbed wire was sent to the front.<sup>16</sup>

Throughout the 1914-1916 period essential innovations occurred in the defence industry. The industry was able to produce the first flamethrowers, new steel helmets, steel bullets which could bypass walls. These bullets were used against observation balloons.<sup>17</sup> According to another source the M-Great type mortars which weighted 42 tons could perish not only fortresses but also submarines bigger than 2,000 tons, when acting as naval guns.<sup>18</sup>

### **Shell production and artillery pieces (1914-1916)**

At the beginning of the war the German army had a huge amount of different types of equipment. In 1916 there were 43 different types of artillery and the number had increased to 77 different types by April 1917. At the beginning of the war there were 200 different artillery shells however their number was reduced to 90 by the end of the war.<sup>19</sup>

The German OHL was facing similar problems of logistical support with those of the French and the British armies. During the 1870-1871 war 199 shells were allocated to every gun. Throughout the war the artillery consumed 670,000 shells.<sup>20</sup> According to one source in 1914 987 shells were allocated in every field artillery piece and 973 shells were allocated in every howitzer. This amount however was consumed in six weeks time.<sup>21</sup> However according a

<sup>12</sup> See: John Walter: "The Greenhill Dictionary of Guns and Gunmakers", Greenhill Books, 2001, page 151.

<sup>13</sup> See: John Walter: "The Greenhill Dictionary of Guns and Gunmakers", Greenhill Books, 2001, page 151.

<sup>14</sup> See: John Mosier: "The Myth of the Great War. A New Military History of World War One", Profile Books, London, 2001, page 159.

<sup>15</sup> See: E.D. Brose: "The Kaiser's Army", Oxford, 2001, page 227.

<sup>16</sup> See: Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, page 244.

<sup>17</sup> See: N. Ferguson: "The Pity of War", Penguin books, 1998, page 290.

<sup>18</sup> See: 1) David Stevenson: "Armaments and the Coming of War. Europe 1904-1914", Oxford, Clarendon Press, 2000, page 22, 2) R.J Winklareth: "Naval Shipbuilders of the World", Chatham Publishing, London, 2000, page 268.

<sup>19</sup> See: Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 1,033. For an analytical work on all types of artillery and their ammunition see: Herbert Jager: "German Artillery of World War One", The Crowood Press, 2001.

<sup>20</sup> See: Herbert Jager: "German Artillery of World War One", The Crowood Press, 2001, pages 194 and 217.

<sup>21</sup> See: 1) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 16, 2) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 993-994.



different source the average amount of shells per artillery type was 858,8 shells for 6,354 artillery pieces. The numbers varied from just 386 shells per piece (for artillery pieces type 10.5 cm leichte Feldhaubitze), to 1,425 shells per piece (for artillery pieces type 10 cm Kanone).<sup>22</sup> By November 1914 the field artillery pieces of the Fourth German Army in Ypre had a maximum consumption level of 13,440 shells per day, that is half an ammunition train. For howitzers the maximum daily amount was 4,000 shells that is one third of an ammunition train load.<sup>23</sup>

In order to meet demand the OHL set a target of monthly production for 200,000 shells. This should be achieved 12-16 weeks after the mobilisation. The target was achieved since only the production of Krupp increased from 150,000 shells before the war to 170,000 in just four weeks time. However other companies were not so successful. To illustrate, AEG signed a contract for 150,000 shells in September 1914 per month, but the actual delivery was just 80,000, many of them were not equivalent to the standards of the army.<sup>24</sup> The monthly powder production increased from 1,200 tons in August 1914 to 6,000 tons six months later. In August 1914 the monthly production of gun tubes was 15 pieces and this was increased to 100 pieces by December 1914.<sup>25</sup>

During the August-December 1914 total shell consumption increased by 260%. In December 1914 the monthly production for field artillery was 1,200,000 shells, whereas the monthly production for howitzers was 414,000 shells, this is seven times the level of August. According to Herwig (1997) shell production in the towns of Siegburg, Spandau, Ingolstadt, Dresden increased from 147,333 pieces in August 1914 to 398,953 in December 1914 and to 486,755 in February 1915. Comparing ammunition production during the August-December 1914 period a 400% increase was observed and comparing October 1915 with August 1914 the increase was 1,300%.<sup>26</sup> The total output of shells during the period August-December 1914 was as follows: 66,000 for mortars, 52,000 for 10cm guns, 618,000 for heavy howitzers, 1,300,000 for light howitzers and 3,200,000 for field guns. Thus in total 5,236,000 shells were produced.<sup>27</sup>

During 1915 the daily shell production reached the level of 250,000 pieces. (During the same time in Britain the daily production was just 22,000 pieces the well known shell-scandal). By the end of the year the monthly production of shells for field artillery was 2,100,000 pieces, whereas the monthly production for light howitzers was 800,000 pieces. During the autumn of 1915 daily shell consumption was 349 pieces for field artillery and 325 pieces for light howitzers. By the end of the year only the 73% of total shell production has been used.<sup>28</sup> The

<sup>22</sup> See: Herbert Jager: "German Artillery of World War One", The Crowood Press, 2001, page 194.

<sup>23</sup> See: 1) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 16, 2) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 993-994.

<sup>24</sup> See: Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 1,032-1,033.

<sup>25</sup> See: Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, page 255.

<sup>26</sup> See: Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, page 167.

<sup>27</sup> See: Mark Osborne Humphries & John Maker (eds.): "Germany's Western Front 1915", Wilfrid Laurier University Press, 2010, page 383.

<sup>28</sup> See: 1) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 1,037, 2) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 65. At this point we

total output of shells for the January-December 1915 period was as follows: 850,000 for mortars, 1,180,000 for 10cm guns, 6,500,000 for heavy howitzers, 8,200,000 for light howitzers, and 21,500,000 for field guns. Thus in total 38,230,000 shells were produced.<sup>29</sup>

However it was not just the increased quantities which were produced during 1914-1915 period. More important was the fact that the quality of the shells was improved as well. The shells were produced by two types of production processes. The former was known as the Thomas-process, whereas the latter was known as the Martin-process. The former was qualitatively superior to the latter. From the beginning of 1915 and in spite of the strong opposition by the industry the OHL cancelled all contracts for shells and grenades of the Martin process, and focused exclusively on Thomas made ammunition which used better steel and more TNT.<sup>30</sup>

Turning our attention to artillery production we have to state that during the 1914-1915 period the level of production was low mainly due to the huge captured equipment in the Western as well as Eastern fronts. To illustrate only the occupation of Maubeuge in northern France gave to the German Army 600 artillery pieces. The occupation of Longwy provided an additional 100 guns with 250,000 shells. In the Eastern front only in Tannenberg the Russians lost 500 guns, while in 1915 the Germans captured more than 3,000 Russian guns with millions of shells. Furthermore in 1914 180 field artillery pieces were confiscated in Krupp factories. These were an order for the Brazilian army which under the circumstances the government cancelled.<sup>31</sup>

According to some sources during the war 3,000 guns needed every month some kind of repair. Only during the first year of the war Krupp alone had to fix some kind of default in 1,535 artillery pieces, and had to produce 1,264 new guns. In 1915 2,300 field artillery pieces and 900 light howitzers were destroyed due to early firing. During the first months of the battle of Verdun (February-May 1916) only the 5<sup>th</sup> Army had to rectify 945 artillery pieces and abandon 571 which had been destroyed due to some kind of failure.<sup>32</sup>

During 1916 the daily shell production in the towns of Dresden, Siegburg, Spandau and Ingolstadt increased from 1 million in June 1915 to almost 3 million in February 1916.<sup>33</sup> According to one source the monthly production of Krupp during 1916 was 3,000 guns and 9 million shells. And this was the production of one firm alone.<sup>34</sup> During the same year

---

have to stress that the Western Front absorbed the 75% of war material, whereas the Eastern Front absorbed the remaining 25%.

<sup>29</sup> See: Mark Osborne Humphries & John Maker (eds.): "Germany's Western Front 1915", Wilfrid Laurier University Press, 2010, page 383.

<sup>30</sup> See: 1) Gerald D. Feldman: "Army, Industry and Labor in Germany 1914-1918", Berg second edition, 1992, page 57, 2) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 1,027-1,028.

<sup>31</sup> See: Lothar Gall: "Krupp im 20. Jahrhundert", Siedler Verlag, Berlin, 2002, page 40.

<sup>32</sup> See: 1) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 1,037 and 2) E.D. Brose: "The Kaiser's Army", Oxford, 2001, page 229.

<sup>33</sup> See: Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, page 167.

<sup>34</sup> See: William Manchester: "The Arms of Krupp", London, Back Bay Books edition, 2003, page 293. This information contradicts Lothar Gall: "Krupp im 20. Jahrhundert", Siedler Verlag, Berlin, 2002, page 50, who points out that until the beginning of the Hindenburg Programme the monthly shell production was just 2,500,000 pieces. Gall points out that the army requested the monthly production of 9,000,000 shells only after September 1916. We shall come back to this point later when we will provide new evidence on German defence production.

machine gun production accelerated as well. In the middle of 1916, according to one source, the monthly machine gun production had reached the astonishing level of 2,300 pieces.<sup>35</sup>

The number of ammunition trains towards the Western Front only increased from 157 in July 1915 to 235 in July 1916. Shell deliveries increased from 3.2 million to 4.5 million and gunpowder deliveries increased from 906 tons to 2,436 tons (always monthly data). Only in August 1916 643,000 shells were used. In September the number was up to 907,000. Only the 8<sup>th</sup> Army Corp reported monthly consumption of 1 million shells, and the 79<sup>th</sup> Field Artillery Regiment used 677,100 shells during 1,811 days of battle.<sup>36</sup>

When the OHL started the attack on Verdun (21-2-1916) the German artillery started its preliminary bombardment at 7:15 in the morning until 16:00 in the afternoon. The Germans were firing 100,000 shells per hour, and only for the initial phase of the attack they had at their disposal 1,300,000 shells.<sup>37</sup>

### **The Hindenburg Programme (1917-1918).**

When Hindenburg and Ludendorff were appointed commanders of the OHL (August 28<sup>th</sup> 1916), they decided that the armaments production should be tripled. The new leadership demanded huge quantities. They demanded a monthly production of 3,000 artillery pieces, 7,000 machine-guns, 1,000 aeroplanes, 1,000 aeroplane engines, and double ammunition production. They also demanded an increase of the labour force in the defence industries by 3,000,000 workers. Everything should be achieved by spring 1917 at the latest.<sup>38</sup>

The new OHL leadership met the main leaders of the industry (Krupp and IG Farben) on September 9<sup>th</sup> 1916. On September 16<sup>th</sup> 39 main industrialists reported to the War Ministry that more workers were needed for the additional armaments production. They requested the increase of Belgium workers and other skilled employees. On 27 September 1916 the OHL requested better food rations for the workers in the defence industry in an effort to increase productivity and by the 30<sup>th</sup> of September the War Ministry decided to merge the main armaments and ammunition committees creating a single one under the title WUMBA (=Waffen und Munitions Beschaffungsamt).<sup>39</sup> On December 5<sup>th</sup> 1916 the new Law for Auxiliary Service was ratified by the parliament. According to this all men aged 17-65 years old had to be employed by the defence industry, or work in agriculture or serve in the military.<sup>40</sup>

<sup>35</sup> See: E.D. Brose: "The Kaiser's Army", Oxford, 2001, page 227.

<sup>36</sup> See: Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, pages 248-249. Obviously the last piece of information goes beyond the 1914-1916 period.

<sup>37</sup> See: Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 101.

<sup>38</sup> See: 1) Roger Chickering: "Imperial Germany and the Great War 1914-1918", Cambridge University Press, 1998, page 76, 2) Paul Kennedy: "The Rise and Fall of the Great Powers. Economic Change and Military Conflict from 1500 to 2000", Fontana Press 1989, page 348. 3) Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997, page 260. The increase of the labour force would occur in two stages. In the first stage (September 1916) 1.2 m. workers were drafted in the industry. The second stage (July 1917) another 1.9 m. workers were employed by the defence industry. Thus the initial target for spring 1917 was not met.

<sup>39</sup> See: 1) Randal Gray et al: "Chronicle of the First World War", Volume I (1914-1916), Facts on File, 1991, pages 245, 247, 251, 2) Gerald D. Feldman: "Army, Industry and Labor in Germany 1914-1918", Berg, second edition, Oxford, 1992, pages 162-168. Even after the establishment of the WUMBA, six major departments existed thus the bureaucratic rigidities were still present. It is interesting that in the case of World War II the level of bureaucracy was also immense, despite the efforts of Speer after 1942.

<sup>40</sup> The whole text can be found in: Gerald D. Feldman: "Army, Industry and Labor in Germany 1914-1918", Berg, second edition, Oxford, 1992, pages: 535-541.

The armaments production increased massively. The monthly production of heavy artillery was increased from 150 pieces to 300 pieces. Field artillery increased from 800 to 1,800 and machine-guns were increased from 2,300 to 14,500 pieces per month. The monthly production of rifles was above the requested target by 250,000 pieces. Monthly production of ammunition increased from 6,000 tons to 12,000 tons and the new technology allowed only the 83% of the quantities of explosives which were used before in shell production to be used now. According to a different source the monthly artillery production in 1917 was 2,000 guns, and the monthly machine gun production was 9,000 pieces.<sup>41</sup> From the 20,000 guns that the German army had at its disposal in 1918 8,000 were heavy.<sup>42</sup> During 1918 the German defence industry produces more ammunition compared to the maximum amount of World War II.<sup>43</sup> According to another source the monthly shell production increased from 343,000 pieces in 1914 to 11,000,000 in 1918.<sup>44</sup>

The case of the main Krupp factory, the Gusstahlfabrik (with 41,682 employees) is very informative. According to one source after the 8<sup>th</sup> of August 1918 (Black Day of the German Army) the company received an order for 85 tanks, and could produce 4,000 shells per hour and 1 new gun every 45 minutes of the hour.<sup>45</sup> According to another source the number of Minnenwerfen increased from 180 pieces in August 1914 to 16.127 in January 1918.<sup>46</sup>

However other sources challenge the above data. To illustrate, according to Grebler & Winkler (1940) although initially the Hindenburg Programme set the target of 3,000 field artillery pieces per month, the quota was reduced to just 1,500 guns in May 1917 and a further reduction occurred in September 1917 for a quota of just 1,100 guns. This was due to labour force shortages.<sup>47</sup> Problems occurred also in aviation industry. According to one source the target of the so called America program of July 1917 was demanding the monthly production of 2,000 aeroplanes and 2,500 aeroplane engines. However the industry could not meet the above targets. Thus the quota numbers were reduced, to just 1,600 aeroplanes and 1,800 aeroplane engines.<sup>48</sup>

<sup>41</sup> See: 1) E.D. Brose: "The Kaiser's Army", Oxford University Press, 2001, London, page 238, 2) Maur. Crouzet: "World History of Civilization", Spyropouloi & Koumoundoureas, Athens 1959, Greek edition page 667.

<sup>42</sup> See: J.M. Winter: "The Experience of World War I", Greenwich editions, 2003, page 138.

<sup>43</sup> See: Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 209. At this point we stress that total ammunition production in 1944 was 3,350,000 tons. The monthly production in 1944 was 307,000 rifles, 28,700 machine guns, 486 million bullets. See: J. Walter: "Guns of the Third Reich", Greenhill Books 2004, page 17. Speer himself admitted that the production of small arms and ammunition was higher during World War I compared to World War II. See: A. Speer: "Inside The Third Reich", Phoenix editions, 2002, pages: 299 and 717-718.

<sup>44</sup> See: Herbert Jager: "German Artillery of World War One", The Crowood Press, 2001, page 196. A spectacular diagram which demonstrates German armaments production during the war can be found in the catalogue of exhibits entitled: Der Todt als Maschinist: der industrialisierte Krieg: 1914-1918: eine Ausstellung des Museums Industriekultur Osnabruck im Rahmen des Jubiliums "350 Jahre Westfälischer Friede", 17 Mai-23 August 1998: Katalog Rolf Spilker, Bernd Ulrich eds. Bramsche: Rasch 1998.

<sup>45</sup> See: William Manchester: "The Arms of Krupp", London, Back Bay Books edition, 2003, page 311.

<sup>46</sup> See: Hew Strachan: "The First World War", Simon & Schuster 2003, page 168.

<sup>47</sup> See: Leo Grebler & Wilhelm Winkler: "The Cost of World War to Germany and to Austria-Hungary", New Haven, Yale University Press, 1940, page 58.

<sup>48</sup> See: Martin Kitchen: "The German Offensives of 1918", Tempus, 2001, page 16.

The increased defence production was demonstrated at the front. To illustrate, when the Kaiserschlacht started (21-3-1918) the German artillery used in the first five hours 1,200,000 shells. During that first day the Germans used 3,200,000 shells targeting the main places of the attack and across the whole line of the Western Front that single day the Germans used 4,300,000 shells. This is more than double the amount that the British used in the first week of the Somme.<sup>49</sup> According to the Official History of the German Army the monthly consumption rate of artillery shells during 1918 alone was varied between 1,082,000-7,842,000 rounds for field artillery, whereas for light field artillery the amount was 531,000-3,792,000 shells.<sup>50</sup>

At this point we have to stress that the success or failure of defence production was also the outcome of available raw materials (steel, iron, coal). The raw material situation was rapidly deteriorating. To illustrate WUMBA reported on the 23<sup>rd</sup> of January 1917 that all the targets of the programme could not be met. By February 1<sup>st</sup> 1917 steel production was lower by 252,000 tons compared to the requested quota. The inputs in the defence industry were huge. According to one source the total inputs of raw materials to the defence industry during the 1914-1918 period were 20,884,000 tons for the Entente powers and 17,267,000 tons for the Central Powers. The numbers during 1917 were 68,107,000 tons and 19,610,000 tons respectively.<sup>51</sup> According to another source only during 1918 the German ammunition industries were absorbing 400,000 tons of steel per month.<sup>52</sup> In spite of the shortage of raw materials on December 4<sup>th</sup> 1917 Ludendorff requested a 10% increase of military production. By the 8<sup>th</sup> of December he was considering the profits of the armaments industry as huge.<sup>53</sup>

In spite of the inability to know exact numbers for every type of defence article the huge increase of German industrial production is documented from the material which was surrendered to the Allies in November 1918. At that time the German armed forces surrendered the following equipment: 5,000 artillery pieces (from those 2,500 were heavy), 25,000 machine guns (from an initial allied request for 30,000), 3,000 Minenwerfer, 1,700 aeroplanes (from an initial request of 2,000), 5,000 trucks (from initial request of 10,000), 5,000 locomotives with 150,000 wagons, 10 battleships, 6 battle-cruisers, 8 light cruisers, 50 destroyers, 176 submarines. Furthermore, the Allied Control Committee confiscated during the 1919-1925 period the following additional defence articles: 33,544 guns, 23,046 gun tractors, 11,615 Minenwerfer, 87,946 machine guns, 242,449 boxes with machine gun ammunition, 4,553,947 small arms, 3,500,000 shells, 5,000,000 shells for Minenwerfer, 490,000,000 cartridges, 12,300,000 hand grenades, 1,072 flamethrowers, 31 armoured trains, 59 tanks, 1,762 observation wagons, 8,972 radio devices, 211,995 telephones, 2,196 pontoons, 8,230,328 sets for private equipment as well as additional equipment.<sup>54</sup>

<sup>49</sup> See: 1) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 162, 2) Martin Kitchen: "The German Offensives of 1918", Tempus, 2001, page 63.

<sup>50</sup> See: Hermann Cron: "Imperial German Army 1914-1918, Organisation, Structure, Orders of Battle", Hellion editions, 2006, pages 141-142. (this is the British edition of the original 1937 German edition).

<sup>51</sup> See: Dietrich Eichholtz: "Geschichte der deutschen Kriegswirtschaft 1939-1945", Band III (1943-1945), Teil I, Munchen 2003, pages 101-102.

<sup>52</sup> See: Adam Tooze: "The Wages of Destruction. The Making and Breaking of the Nazi Economy", Allen Lane, 2006, page 340.

<sup>53</sup> See: Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume II (1916-1921), Facts on File, 1991, pages: 13, 17, 19, 115.

<sup>54</sup> For the initial quantities which were granted to the Allies in November 1918 see: M. Gilbert: "The Versailles Treaty", in the work: "History of the 20<sup>th</sup> Century" Parnell, Volume 2, Greek edition, pages 886-902 and especially page 897. See also: S. Skondras & K. Korovilas: "History of World War I 1914-1918", Kekrops publications Athens, 1969, volume 3, pages 319-321. For slightly modified data on the ships which were

**Naval equipment (1914-1918).**

Turning to naval production we can refer to Ellis & Cox (2001) who point out that during the war the German shipyards produced 359 submarines, when total losses were 178, and 372 surface vessels were constructed when total losses reached 342 vessels.<sup>55</sup> Turning to torpedoes in September 1918 774 were produced four times more the level of 1913.<sup>56</sup> Also in 1918 Germany had under construction 149 new submarines under the Sheer programme.

**German Military Assistance abroad (1914-1918).**

Throughout the war Germany provided enormous financial as well as military assistance to its allies. For the purpose of this paper we focus exclusively on military assistance, which was as follows:

Germany provided the following equipment to Austria-Hungary: 447 aeroplanes, 112,747 rifles (from those 12,000 were Russian captured), 632 machine-guns, more than 12,000 pistols of all kinds, 136,000,000 cartridges, 100,000 helmets, 4,135 artillery pieces (from those 22 were Russian captured and 13 were Belgian captured), 1,827,700 shells, 966,475 gas masks, 548 vehicles, 94,500 blankets. Furthermore, raw materials valued at 690m Marks was granted.<sup>57</sup>

The total German military aid to the Ottoman Empire was as follows: 559 artillery pieces, 557,000 rifles, 100,000 light rifles, 1,570 light machine guns, 30 heavy machine guns, 200,000 artillery shells, 500,000 detonators, 930,000,000 cartridges, 30 flamethrowers, 1,000 vehicles, 16,000 gas masks, 244 telephones, 20 telecommunication centres, 120 locomotives, 460 aeroplanes, and other equipment. The value of military aid was 616m Marks.<sup>58</sup> Obviously one has also to take into consideration the initial transfer of "Goeben" and "Breslau", the two battle-cruisers which the German handed to the Ottoman navy in 1914.

The German military aid to Bulgaria was also impressive. Bulgaria received 230,000 rifles, 1,950 machine guns, 22,000 pistols, 235,000,000 cartridges, 403 artillery pieces, 8,225,000

---

surrendered see: P.G. Halpern: "A Naval History of World War I", UCL Press, 1994, page 448. For the quantities which were confiscated during the 1919-1925 period see: Philip Noel Baker: "The Private Manufacture of Armaments", 1972 edition London, page 378.

<sup>55</sup> See: John Ellis & Michael Cox: "The World War I Databook", Aurum Press, London, 2001, pages: 275, 276, 288. According to Gall (2002) Krupp alone received an order for 144 torpedo boats. These should have been delivered at the latest by the 29<sup>th</sup> month after the signing of the contract. See: Lothar Gall: "Krupp im 20. Jahrhundert", Siedler Verlag, Berlin, 2002, pages 39-40. See also Table 5a (in section 4).

<sup>56</sup> See: Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume II (1916-1921), Facts on File, 1991, page: 211.

<sup>57</sup> See: Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume I, page 117 and Volume II (1916-1921), page 292, Facts on File, 1991. From the 112,747 rifles the 70,000 were of the old type Gewehre 88. These were handed to Austria-Hungary during 1915-1916 but later most of them were sent from Vienna to Ottoman Empire. See: John Walter: "The Greenhill Dictionary of Guns and Gunmakers", Greenhill, London, 2001, page 425.

<sup>58</sup> See: 1) Edward Erickson: "Ordered to Die: A History of the Ottoman Army in the First World War", Greenwood press, 2001, page 233, 2) Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume I, page 176 and Volume II (1916-1921), page 292, Facts on File, 1991. Slightly different data are presented in the S. Pamuk: "The Ottoman Economy in World War I" in the volume: S. Broadberry & M. Harrison (eds.): "The Economics of World War I", Cambridge 2005, pages: 112-136, and especially page 117. The issue is discussed also in Ulrich Trampener: "Suez, Baku, Gallipoli: The Military Dimensions of the German-Ottoman Coalition 1914-1918", in the volume: B. Kiraly & N.F. Dreisziger (eds.): "War and Society in East Central Europe", Vol. XIX, Columbia University Press, 1985, pages 381-400.

conventional shells, 80,000 chemical warfare shells, 400,000 gas masks, 450 vehicles, 140 locomotives, 1,200 wagons, 6 VHF (Very High Frequency) radio stations, 5,000 telephones, 450 telegraphic devices, 560,000 uniforms, 600,000 rain coats, 1,420,000 pairs of boots. The value of the total military aid was 1,074m Marks.<sup>59</sup>

In 1918 the Germans provided military assistance to the anti Bolshevik forces. This consisted of 11,000 rifles, 46 guns, 100,000 shells, 88 machine guns, more than 1,000,000 bullets. Additional economic aid of 15m roubles was also granted.<sup>60</sup>

In an attempt to create problems to the colonies of France the Germans attempted to finance and arm rebellion movements in Morocco. The first attempt to arm the rebels occurred in 1915 and the plan was to send (smuggle) 5,000 small arms with 500,000 bullets into the country. However the plan failed when the Spanish police confiscated 3,000 rifles. The second attempt occurred in July 1916 when the Germans offered 3,000 rifles and 2,000,000 cartridges.<sup>61</sup>

The Germans attempted to provide assistance to rebels in British colonies as well. In 1915 the Germans send to Persia 6 machine guns and 20,000 rifles planning to equip local tribes.<sup>62</sup> In order to equip anti-British forces in India the German embassy in the US bought the following equipment: 10,000 rifles, 4,000,000 cartridges. A second shipment, consisting of 7,300 rifles, 1,920 pistols, 3,000,000 cartridges and 10 artillery pieces was also bought. These, however never reached India.<sup>63</sup> However the Germans failed to meet the demands of anti-British forces in Afghanistan which asked for 100,000 rifles and 300 guns, and equipment for arming at least 70,000 men.<sup>64</sup> Finally the Germans attempted, again unsuccessfully, to ship 36,000 rifles to Ireland in March 1916 in order to assist the rebels.<sup>65</sup>

In the isolated German colonies in Africa the Germans had accumulated vast quantities of material and were able to assist them during the war. When the allies made their first quick victory in German Togoland (26 August 1914) they captured 3 machine guns, 1,000 rifles, and 320,000 cartridges.<sup>66</sup> In the German colony of Cameroon the story was not so easy. The company resisted until February 1916. When the last German garrison of 155 men surrendered the allies confiscated 37,000 cartridges.

The third case of German South West Africa surrendered to the Allies in July 1915. The Germans surrendered 37 guns, 22 machine guns, 2,000,000 cartridges and huge quantities of shells.<sup>67</sup> The most difficult case was that of the German East Africa which surrendered to the Allies in 1918. The small garrison of the colony was reinforced first in November 1914 by

---

<sup>59</sup> See: 1) Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume II (1916-1921), Facts on File, 1991, page: 292, 2) G. Hardach: "Der Erste Weltkrieg 1914-1918", DTV, 1973, page 84.

<sup>60</sup> See: Martin Kitchen: "A Military History of Germany", The Citadel Press, 1976, page 228.

<sup>61</sup> See: Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 766-768.

<sup>62</sup> See: Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 788.

<sup>63</sup> See: Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 792-798.

<sup>64</sup> See: Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 774.

<sup>65</sup>

<sup>66</sup> See: 1) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 508 and 2) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 191.

<sup>67</sup> See: 1) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, page 568 and 2) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, page 193.

war material captured by the British. The supplies of German forces were huge. This consisted of 16 machine guns, 600,000 cartridges and hundreds of rifles.<sup>68</sup> On the other hand consumption of ammunition was also high. To illustrate only [until] January 1915 the forces of Lettow-Vorbeck have used 200,000 rounds of ammunition.<sup>69</sup>

In 1915 the German cruiser “Konigsberg” was able to deliver to the local German forces 10 artillery pieces of 105mm, 1,000 shells of 105mm, huge quantities of shells for 47mm light artillery, 1,800 rifles, 3,000,000 cartridges, 2 guns of 60mm, 6 machine guns, huge quantities of dynamite, clothes, medical equipment and material, food and various tools.<sup>70</sup> This was the only successful shipment of material from Germany to the German East Africa.

### The chemical weapons (1914-1918)

During the 1914-1918 period 68,100 tons of various types of gases were produced and 52,000 tons were used.<sup>71</sup> The importance of companies like BASF, Bayerische Stickstoffwerke was immense. The financial assistance of the Deutsche Bank was also essential.

### Overall data of German defence production (1914-1918).

We have presented an anthology of data regarding the German defence production. The following tables provide aggregate data on the evolution of defence production.

**Table 4: Military Production-Main Army Defence Articles**

	1914	1915	1916	1917	1918	Total
Tanks						<b>20</b>
Artillery	800 (1,200) (520)	3,816 * (8,000) (3,240) (1,180+)	2,382 ** (5,760) (14,300)	24,000 (25,200) (23,316)	17,453 (a) (20,000)	<b>64,000</b>
Mortars			1,684	15,933	17,127	<b>34,744+</b>
Vehicles	3,500	12,000	18,000			
Armour Cars						<b>37</b>

**Sources:** See Table 4b. (\*)=The 456 were heavy guns. The 8,000 refers to estimate for both years 1914 and 1915. (\*\*)=More than 1,320 were heavy guns, (a)=From those 1,903 were heavy.

<sup>68</sup> See: John Keegan: “The First World War”, Pimlico, London, 1998, page 230.

<sup>69</sup> See: Edward Paice: “Tip & Run The Untold Tragedy of the Great War in Africa”, Weidenfeld & Nicolson, London, 2007, page 83. However it is unclear if this was the consumption of one single battle or of all conflicts between allied and German forces until the beginning of January 1915.

<sup>70</sup> See: Spencer Tucker: “The Great War 1914-1918” UCL Press, London 1998, page 194.

<sup>71</sup> See: 1) Hew Strachan: “The First World War: To Arms”, (Volume I) Oxford University Press, 2001, pages 1.025-1027, 2) Spencer Tucker: “The Great War 1914-1918” UCL Press, London 1998, page 209, 3) Roger Chickering: “Imperial Germany and the Great War 1914-1918”, Cambridge University Press, 1998, page 38, 4) Randal Gray et al: “Chronicle of the First World War”, Volume II, page 288.



**Table 4a: Military Production-Army Defence Articles-Light equipment**

	1914	1915	1916	1917	1918	Total
Machine guns	5,550	7,200	27,600	108,000	196,578	<b>344,928</b>
	1,000	6,100	61,800	174,000	157,300	<b>347,878</b>
	2,400	9,600		172,800		<b>401,500</b>
				115,200		<b>405,278</b>
Rifles	345,000 *	360,000	432,000 3,000,000	3,000,000		<b>6,705,000+</b>
Hand grenades						<b>300,000,000 (**)</b>
Shells		78,750,000	110,000,000	168,000,000	84,000,000	<b>350,000,000 (***)</b>
Powder (in tons)	8,525	57,000	96,000	144,000	157,300	<b>462,825</b>
	8,000				145,200	
Explosives in tons	14,400	72,000	120,000	144,000	168,000	<b>518,400</b>
Cartridges						<b>(a)</b>
Trench barriers (b)		2,000	5,000-7,000	7,000	4,000-	<b>635,000</b>
		3,000			5,000	
		7,000				

**Sources:** See Table 4b (\*)=For the period August-December production was 43,200.

According to Grebler & Winker (1940), page 42 the total small arms production during the war was 10,000,000. (\*\*)=Only in 1918 German hand grenade production was 56,400,000 pieces. Data from "Germany and the Second World War" Volume V/II, Oxford, 2003, page 692. (\*\*\*)=The amount of 350m shells is the minimum estimate. We arrive to this considering the following: According to H. Jager: "German Artillery of World War One", The Crowood Press, 2001, page 218 the German artillery during the war consumed 272 million shells. These were distributed as follows: 156 million shells were fired from 7.7 cm FH/K guns, 67 million shells were fired from 10.5 cm FH guns, and 7 million shells were fired from Minenwerfer. The above data refer to **consumption** of shells not **production**. To this number we have to add the shells which the allies confiscated in 1918-1925 period, the shells which were given to the other members of the Central Powers and we have to take into consideration supplies to the Imperial German Navy as well. Obviously Germany had acquired huge amounts of ammunition from victories across various fronts throughout the war. To illustrate, just in 1915 in the Eastern front campaign the capture of Novogorod and Kovno fortresses gave to the German 2,900 guns and 1,900,000 shells. See: N. Stone: "World War One A Short History", Penguin, 2007, pages 70-71. (a)=The ability to calculate the number of cartridges is extremely difficult, since the various sources provide conflicting information. According to one source the German soldier was equipped with 70 rounds (for rifles). See: Gary Sheffield: "War on the Western Front", Osprey, 2007, page 19. This excludes the ammunition for machine guns and sub-machine guns. Assuming that 3.5 million men of the Army were using rifles (the actual number can be higher), only the initial provision of cartridges would be near to 24,500,000,000 rounds per operation. However, according to another source in 1914 every rifleman of the army was equipped with 280 rounds of ammunition. See: Martin Van Crevel: "Supplying War", Cambridge University Press, 2004, page 110. Obviously the total number in this case is four times (!) the previous estimate. (b)=Weekly production in tons. The data for 1915 refer to the months July, August,

December, Average production for 1916, and 1918. Total production by the middle of 1918. According to another source in 1917 the Germans had 535,000 km of barbed wire in the Western Front and 355,000 km in the Eastern Front. The average monthly consumption of barbed wire was 250 litres per mile of front. See: M.V. Creveld: "Command in War", Greek edition, Athens 2001, page 341, footnote 26.

**Table 4b: Military Production-Air Force**

	1914	1915	1916	1917	1918	Total
Aeroplanes	1,348 (694)	4,532 (4,400) (2,950)	8,182 (8,100) (7,112)	19,746 (19,400) (13,997)	20,971 (14,123) 6,528 *	47,931 45,724 38,428+
Aeroplane Engines	848	6,007 5,037	7,823 7,822	12,029 11,200	15,452 15,153	41,860 40,449 38,808
Balloons						62

According to another source the production of aeroplane engines during the 1914-1919 period per firm was as follows: Daimler: 19.876, Benz: 11.360, Oberursel: 2.932, Opel: 2.260, Argus: 1.257, Maybach: 1.123. See: Bernard P. Bellon: "Mercedes in Peace and War", Columbia, University Press, 1990, page 87.

**Additional sources for Tables 4-4b:** 1) Gerald D. Feldman: "Army, Industry and Labor in Germany 1914-1918", 1992, 2) Gerald D. Feldman: "The Great Disorder. Politics, Economics and Society in the German Inflation 1914-1924", Oxford University Press, 1997, 3) Martin Gilbert: "The Routledge Atlas of the First World War", Routledge, second edition, London, 1994, 4) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pages 815-1.113, 5) John Ellis & Michael Cox: "The World War I Databook", Aurum Press editions, London, 2001, 6) Albrecht Ritschl: "The Pity of Peace: Germany's Economy at War 1914-1918 and Beyond", paper presented in Warwick conference, UK 8-19 July 2002. Essential information can be found in the following: 1) Robin Prior & Trevor Wilson: "The First World War", Cassel editions, London 2000, 2) M. Crouzet: "World History of Civilization", Spyropouloi & Comoudoureas Athens 1959, page 667, Greek edition referring to production data of 1917, 3) R.J. Overy: "War and Economy in the Third Reich", Oxford, 1995, with important data for 1918 production in page 268, 4) J. M. Winter: "The Experience of World War I", Greenwich editions, 2003, pages 40-42. See also: 5) Norman Stone: "The Eastern Front 1914-1917", Penguin editions, London, 1998, 6) N. Ferguson: "The Pity of War", 1998, 7) Randal Gray et al: "Chronicle of the First World War", Volume II (1916-1921), Facts on File, 1991, pages 290-297, 8) N. Stone: "Europe Transformed 1878-1919", page 209, 9) Lothar Gall: "Krupp im 20. Jahrhundert", 2002, page 46. Also: 10) Gerd Fesser: "Die Kaiserzeit. Deutschland 1871-1918", published in 2000 by the Landeszentrale für politische Bildung, 11) J. Adelman: "Prelude to the Cold War", Lynne Rienner Publishes, 1988, page 45 (Note: For naval armaments see earlier in the text).

## A RE-ASSESSMENT OF THE GERMAN DEFENCE PRODUCTION.

The current bibliography, demonstrates, that in quantitative terms the Germans outperformed the Allies on a single basis. This is correct, but is this the complete story? To put it differently was the German industrial effort **efficient** and the allied effort **inefficient**? Efficiency is related with the maximum mobilization of resources and with optimum production. In other

words, we expect that all factors of production (capital, labour, land, etc) are fully mobilised and in an optimum way in Germany, whereas in the Entente countries factors of production are not fully mobilised and not in an optimum way. Is this assumption correct? We shall try to answer these questions. Going back to existing literature we point out that there is considerable evidence which hints that German industrial production has not achieved maximum mobilisation of resources or optimum production levels. In other words there is evidence which suggests that industrial production could have been higher. If this is the case then factors of production were not fully mobilised. Do we have evidence about this?

Ferguson (2002) provides evidence for the region of Hamburg pointing out that in the end of 1916 there were 58 enterprises which could produce hand grenades, 34 enterprises which could produce explosives, and an additional 58 enterprises which could produce artillery shells, but they have not received, not even a single contract. Turning to textile industry which was supplying the army with uniforms Ferguson (2002) points out that by December 1915 in Hamburg region again only one third of textile products was absorbed by the army.<sup>72</sup>

Feldman (1992) provides similar evidence from a German firm focusing on detonators and hand grenades production. Thus according to the industrialist of the company, Dr. Walderschmidt the enterprise had no experience on ammunition production until the autumn of 1914. However the company could produce two different types of detonators with a daily capacity of 10,000 pieces. When the company informed the Army the offer was turned down. The army asked for the design of new types of detonators from the beginning.<sup>73</sup>

These are evidence which hint that the German factors of production were not fully used. The question is if these were isolated incidents in a story of a well managed and efficient industry, which outperformed all other opponents or if these incidents are just the tip of the iceberg of a hidden story. Can it be the case that the small and medium sized enterprises (SMEs) were not fully mobilised, or even marginalised, during the war and that the majority of armaments production was delivered by the big firms? (Krupp, Rheinmetall, DWMF etc).

In other words was the German defence production of World War I a story of oligopoly, or even worse a cartel of big businesses which dictated prices to the central government? We are aware that the profits of the major defence industries increased rapidly throughout the war.<sup>74</sup>

In order to answer the question we have to provide evidence of defence production of the big firms. If we know the share of big firms in total armaments production then we are able to calculate, if practically the case of German defence production is a case of dominant big businesses which marginalised SMEs. If this is the case, that is SMEs were not fully mobilised, the story of the efficient German production should be altered. In other words the total production could have been higher, if the SMEs were fully mobilised.

The following table provides evidence for the first time of the production level of Germany's big businesses during World War I. (The data have been published but they come into light for the first time at least for English speaking readers).

---

<sup>72</sup> See: Niall Ferguson: "Paper & Iron. Hamburg Business and German Politics in the Era of Inflation, 1897-1927", Cambridge, 2002, page 105.

<sup>73</sup> See: Gerald D. Feldman: "Army, Industry and Labor in Germany 1914-1918", Berg, second edition, Oxford, 1992, page 56.

<sup>74</sup> For data on profits see: G. Hardach: "Der Erste Weltkrieg 1914-1918", DTV, 1973, page 117.

**Table 5: Production of major arm manufacturers (in absolute numbers and as a % of the total).**

Type of equipment	Total production 1914-1918	Production of Krupp	Production of Rheinmetall	Production of DWMF	Production of Ehrhardt
Artillery	64,000	20,282 (1) (31.7%)	4,000 (6.25%)		4,000 (6.25%)
Mortars	34,744+		14,500 (2) (41.7%)		
Machine guns	405,278			58,000 (14.3%)	
Rifles	6,705,000+			930,000 (13.8%)	
Pistols	2,500,000+			680,000 (27.2%)	
Shells	350,000,000+	19,250,000	9,332,000 (a)	22,000,000 (d)	9,000,000
Hand grenades	300,000,000		5,000,000 (1.6%)		
Explosives (in tons)	518,400				
Powder (in tons)	462,825				
Cartridges			700,000,000	4,000,000 (e)	
Detonators			11,000,000 (b)	580,000,000	
Mines			6,950,000 (c)		

**Sources:** 1) Zdenek Jindra: "Der Rüstungs-konzern Fried. Krupp AG. 1914-1918", initially Ph.D. Dissertation, XCVIII, Charles University Prague, 1983, published as a book, Univerzita Karlova, Praha, CSSR, 1986, page 83, 2) Heinz-J. Bontrup & Norbert Zdwomyslaw: "Die Deutsche Rüstungsindustrie", Diestel Verlag, 1988, pages 90-92. (1)=From the 20,282 Krupp made guns only the 10,843 were fully made, the remaining 9,439 refer to gun tubes and not to fully made guns, (2)=excluding 44,000 mortars for chemical warfare and also 4,000 mortars specialized in firing grenades, (a)=shells of all types for artillery as well as mortars, (b)=joint production between Rheinmetall and Werk Sommerda, (c)=all types (light, heavy, gas mines etc.), (d)=shell parts (explosives for shells) (e)=In addition 111,000,000 spare parts for all types of ammunition, and 990,000 ball bearings.

The above data, certainly incomplete and limited, demonstrate a very interesting picture. It seems that a case of oligopoly existed in critical (important) types of armaments. Thus in the case of artillery three firms control 44.2% of total production. In the case of mortars one firm controls 41.7% of total production. (The real share may be lower since the total number of mortars is unknown, however a high share is still present taking also into consideration point 2 of the table). In rifles only one firm controls almost the 14% of the production, and in pistols the share becomes even higher (27% under the control of one enterprise).

The data are limited however it seems that the big firms controlled the biggest share of the main armaments, whereas the SMEs were the auxiliary producers. The SMEs role was mainly, that of subcontractor, in main armaments industry. However for the production of ammunitions, spare parts and other equipment their role seems to be essential. This conclusion is accruing from regional data as well. To illustrate, in the region of Lippe the local industry was able to produce around 200,000 ammunition cases, 5,000 ammunition boxes, around 1,500 military vehicles, 30,000 trench barriers, 10,000 sacks as well as other equipment of auxiliary nature.<sup>75</sup>

We now turn our attention to a different issue, that of naval armaments. In this case the position of Krupp was very dominant. This is illustrated in Table 5a

**Table 5a: Krupp's share in Naval Armaments (1914-1918)**

Type of Ship	Total production (Absolute number)	Krupp production & % share
Battleships	6	1 (16.7%)
Battle Cruisers	5	-
Light Cruisers	14	-
Destroyers	107	-
Minesweepers	148	-
Torpedo boats	92	22 (24%)
U-boats	359 (356)	79 (22%)
Total Naval Production (Surface Ships)	372	23 (6.1%)
Total Naval Production (U-boats)	359 (356)	79 (22%) (22.2%)
Total Naval Production	731 (728)	102 (14%) (14%)

**Sources:** 1) John Ellis & Michael Cox: "The World War I Databook", Aurum Press, London, 2001, pages: 275, 276, 288, 2) Zdenek Jindra: "Der Rüstungs-konzern Fried. Krupp AG. 1914-1918", initially Ph.D. Dissertation, XCVIII, Charles University Prague, 1983, published as a book, Univerzita Karlova, Praha, CSSR, 1986, pages 97-98.

It is obvious that almost one out of four submarines built for the German Imperial Navy was made by Krupp. The same is the case for torpedo boats. Thus out of the seven types of vessels which the German shipyards produced during the war Krupp has an important production share in two of them. We do not know the exact number of mechanical equipment that Krupp possessed in 1914 and in 1918. However, according to one source, the company in order to fulfil disarmament obligations handed to the Allies 9,300 machines weighting 60,000 tons and 800,000 tools weighting 10,000 tons.<sup>76</sup> With this size of machine tools accumulation the only problem with Jindra's numbers is the one which refers to shell production. It is certainly a huge underestimate.

Another essential issue is the numbers of defence industries in the Second Reich. We do not have a source regarding the total number of firms, their assets, productive capacity etc. However we can have a realistic estimate when we consider data from the era of the...Third

<sup>75</sup> See: A. Ruppert: "Militar und Rüstung in der Region Lippe 1914-1945", Bielefeld, 2001, page 141.

<sup>76</sup> See: R. Lewinsohn: "The Profits of War", New York, 1937, page 161.

Reich. Thus in June 1933 in Germany existed 1,903,420 registered industries which had a total labour force of 8,998,753 workers. The Third Reich at its initial “peaceful” stage (1933-1938) was planning to engage in defence production in case of war around 240,000 enterprises, however those with direct armaments involvement were just 2,500. At this stage we have to remember that because of the Versailles Treaty Germany was unable to have a defence industrial complex. If however at that stage the Third Reich was able to mobilise 2,500 enterprises in weapons procurement, it is rational to assume that the Second Reich, with no restrictions, had more enterprises in the defence sector. Thus for the Second Reich we can assume that a number of 3,000 enterprises was active in the defence industry. From those some had dual purpose character and some others were exclusively defence oriented. However, only a handful of companies, were able to produce en mass critical defence material. (see section 1 and Table 1).

The second issue is related to the concept of economies of scale and scope. In economic theory the economies of scale can be achieved only if production levels increase, but the Average Cost (AC) or per unit cost decreases. The data related to economies of scale are scant. We know that the cost for each artillery shell used by the “Big-Berthas”, against Paris in 1918 was 35,000 Marks. We also know that in June 1918 Ludendorff pointed out, that per unit price, of uniforms and shirts increased by 700% (between 1913-1918) and the prices of boots increased by 300%, over the same period. These data however are too limited in order to deduct conclusions. Furthermore the importance of inflation should also be considered.<sup>77</sup> Thus the presence or absence of economies of scale cannot be documented.

On the other hand the presence of economies of scope can be documented. With the term in economics we refer to the joint production of two or more products from the same production line inside a factory. The limited evidence points out, that, economies of scope, existed in the production of artillery, shells, small arms.

### **COMPARISON OF GERMAN INDUSTRIAL PRODUCTION WITH THAT OF OTHER BELLIGERENTS**

In order to appreciate the capabilities of the German defence industry we have to compare and contrast the German production viz. a viz. that of the other belligerents.

The UK during the war was able to produce the following defence articles: 55,000 aeroplanes, 41,000 aeroplane engines, 2,700 tanks, 25,000 artillery pieces, 240,000 machine guns, 19,000 mortars, 5,090,000 rifles, more than 100,000,000 hand grenades, 217,000,000 shells, 783,600 tons of explosives, more than 8,600,000,000 cartridges, 840 warships.

France was able to produce 52,000 aeroplanes, 92,000 aeroplane engines, 5,300 tanks, 24,000 artillery pieces, 312,000 machine guns, more than 333 armoured vehicles, 142 war ships, 36,955 tons of chemicals.

Italy produced 13,000 aeroplanes, 24,000 aeroplane engines, around 12,000 guns, 31,000 machine guns, more than 3,5 billion cartridges, 24,230,000 small arms of all kinds, almost 70,000,000 shells, 7,300,000 hand grenades, 159 warships, 6,300 tons of chemical gas.

---

<sup>77</sup> See: 1) S.A. Skondras & S.Korovilas: “History of the First World War 1914-1918”, Volume III, Kekrops editions, 1969 Athens, page 279 (in Greek), 2) R.B. Asprey: “The German High Command at War”, Warner Books, 1996, page 402.

Russia produced only a fraction of the above. Almost 4,500 aeroplanes, 15,000 guns, 27,476 machine guns, almost 55,500,000 shells, 4,700 tons of chemical gas, 109 warships, 34,260 metric tons of powder.

The US industrial production exclusively in 1918 was as follows: 1,826 guns, 17,260,000 shells, 226,557 machine guns, 64 tanks, 30,000 vehicles, 4,089 aeroplanes, 16,325 aeroplane engines, 180 warships, 6,215 tons of gas for chemical warfare. However throughout the war years the US supplied to Britain 926,000,000 bullets, 31,000,000 shells, 1,200,000 rifles, 569,000 tons of powder and explosives, 42,000 trucks, 3,400 aeroplane engines, 866 aeroplanes and other material. The US also supplied Russia with 553,000,000 bullets, 970,000 rifles, 24,500 machine guns. In April 1918 the US was sending to France 10,000 tons of supplies daily and by November it had reached 30,000 tons. If the war continued the planned daily deliveries for June 1919 were 90,000 tons. We point out that the US almost reached German production in just 12 months of official mobilisation.<sup>78</sup>

Finally the Austro-Hungarian production was as follows: 4,338 aeroplanes, 4,346 aeroplane engines, 11,561-18,442 artillery pieces, 38,900 machine guns, 66,900,000 shells, 7,900 tons of chemicals, 47 ships.<sup>79</sup>

It is obvious that Germany outperformed the Allies in the production of machine guns, small arms, shells, artillery pieces, hand grenades. However in tanks and aeroplanes German production was problematic. Under the bottlenecks imposed by the raw material situation the German industry emerges as the most efficient across the various belligerents. This is certainly the correct story which the bibliography demonstrates, the question however is if this is the complete story as well. We shall try to address this question in the following paragraphs of the section.

Here we have to stress that the story of the UK, France, Russia, Italy and Austria-Hungary was similar to the German one. To illustrate, in the UK there were three leading defence manufacturers "Vickers", "Royal Ordnance Factories", and "Armstrong". They were followed by seven state shipyards and twenty-seven private ones. The aviation industry was pioneering with firms like "de Havilland", "Royal Aircraft Factory" and later "Rolls-Royce", which during the war years will manufacture airplane engines.<sup>80</sup> In France the leading arms manufacturer was "Schneider-Creusot", with five state shipyards and nine private ones. Aviation industries like "Farman", "Gnome and Rhone, Breguet", "Rossel-Peugot" were set up.<sup>81</sup> In Russia the "Putilov" factories as well as the factories in the towns of Tula, Nikol-

<sup>78</sup> It is impossible to list all available sources regarding defence production of Entente Powers. An overview and extensive discussion can be found in Ioannis-Dionysios Salavrakos: "Economy and Total War", Volume I: The Case of The First World War (1914-1918), Athens, Kritiki publications, Septemeber 2007, pages: 169-271. (in Greek).

<sup>79</sup> See: Ioannis-Dionysios Salavrakos: "Economy and Total War", Volume I: The Case of The First World War (1914-1918), Athens, Kritiki publications, Septemeber 2007, pages: 343-350 for discussion of data. (in Greek).

<sup>80</sup> See: 1) Clive Trebilcock: "The Vickers Brothers Armaments and Enterprise 1854-1914", London, 1977, 2) William H. McNeil: "The Pursuit of Power", Blackwell 1983, especially pages: 262-299 and also: 3) Peter Botticelli: "Rolls-Royce and the rise of high-technology industry", in the volume: Thomas C. McCraw (ed.): "Creating Modern Capitalism", Harvard University Press, 1997, pp: 96-132.

<sup>81</sup> For the French defence industry see: Claude Beaud: "Les Schneider "marchands de canons"", Paper presented in the Workshop: "The Armament Industry and European Economic Development (1870s-1939)", European University Institute, Florence, Italy. See also: R.J Winklareth: "Naval Shipbuilders of the World", Chatham Publishing, London, 2000, pages: 210-226.

Mariupol, Sormovo etc were leading arms producers, with 12 major shipyards and aviation industries in cities like St. Petersburg, Moscow etc.<sup>82</sup> Thus the oligopolistic structure of the defence industry exists also in the Allied / Entente side as well. However, as Tables 6 and 7 point out in most categories of defence articles the Central Powers were outperformed by the Allies, and also they did not enjoy any potential qualitative superiority.

From the data of Table 6 it emerges that although the German industrial production was the highest among belligerents the combined allied production surpassed that of Germany and Austria-Hungary. Thus across all critical defence articles the Allies enjoyed a quantitative superiority. To illustrate the Central Powers produced 79,900 artillery pieces, whereas the Allies produced 102,842 pieces. The Central Powers produced approximately 444,500 machine-guns, whereas the Allies produced 837,563 items. The Central Powers produced approximately 52,300 airplanes, whereas the Allies produced 127,849 airplanes. The production gap between the two opposing alliances is extremely unfavourable for the Central Powers for the case of tanks and other armoured vehicles. The Central Powers produced just 57 items (20 tanks, 37 AIFVs) when the combined allied production was more than 8,821 items (8,188 tanks and more than 633 AIFVs). Finally in terms of naval armaments the Central Powers constructed 517 vessels and submarines, whereas the Allies constructed 886 vessels and submarines.

Thus the German defence industry managed to produce more weapons than any other industry of the belligerent economies; however this production could not balance the combined production of the Allies. This story however, of maximum industrial production was not repeated during World War II, although at that time the German industry had more resources and raw materials from the occupied European countries, than in 1914-1918.

Turning to Tables 7-8 we observe that the Germans did not enjoy any qualitative superiority, over the Allies as well. Just by comparing the characteristics of the most basic defence articles it is obvious that the defence industries of the belligerents produced weapons which had mainly similar characteristics. To illustrate, the standard gun of the French artillery (the famous 75mm) had a standard velocity of 15 shells per minute, far higher than any German gun. However, the range as well as the weight of the shells was smaller compared to the German standards. In the case of machine guns most models had almost similar levels of velocity, range and logistical support.

---

<sup>82</sup> For the Russian defence industry see: 1) N. Stone: "The Eastern Front 1914-1917", Penguin, London, 1998, page 210, 2) P. Gatrell: "Government, Industry and Rearmament in Russia 1900-1914", Cambridge, 1994, page 219, 3) R.J Winklareth: "Naval Shipbuilders of the World", Chatham Publishing, London, 2000, pages: 295-309.



**TABLE 6: Main defence production 1914-1918 of Central Powers viz. a viz. the Allies (1914-1918 maximum estimates)**

	UK	France	Italy	Russia (1914-1917)	US (in 1918)	Germany	Austria-Hungary
Airplanes	55,093	52,146	12,021	4,500	4,089	47,931	4,338
Airpalne-engines	41,034	92,386	24,400		16,325	41,860	4,346
Artillery	25,031	49,190	11,789	15,006	1,826	64,000	15,900
Mortars	19,96			542			
Tanks	2,818	5,300	6		64	20	
Machine-guns	240,500	312,000	31,030	27,476	226,557	405,278	38,900
Rifles	5,090,442	2,500,000 +	24,230,000 (pistols included)			6,705,000 +	
Grenades	100,102,719		7,300,000			300,000,000	
Shells	217,000,000	244,884,380+	69,835,000	54,000,000		500,000,000	183,000,000 +
Armoured Vehicles	300+	333+				37	
Gun-powder (in t.)						462,825	
Explosives	783,600	75,500+				518,400	
Bullets	8,637,112 (in 000)		3,616,000 (in 000)	148,200,000 +			
Battleships	13	3	3	7	6	6	1
Cruisers	59	-	2	-		19	3
Destroyers	329	6	28	36	77	107	5
Aircraft carriers	16	4	1	7		0	
Submarines	98	25	71	40	55	359	17

**Selected Sources:** 1) Ioannis-Dionysios Salavrakos: "Economy and Total War, Vol. I The Case of the First World War (1914-1918)" Athens, Scientific Library series, Kritiki publications, September 1997, 2) John Ellis & Michael Cox: "The World War I Databook", Aurum Press editions, London, 2001, 3) Randal Gray: "Chronicle of the First World War", Facts on File, London 1991, 4) Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001, pp: 993-1,113, 5) E.D. Brose: "The Kaiser's Army", Oxford University Press, 2001, London, 6) N. Ferguson: "The Pity of War", Penguin books, 1998, 7) G D. Feldman: "Army, Industry and Labor in Germany 1914-1918", Berg, second edition, Oxford, 1992, 8) Lothar Gall: "Krupp im 20. Jahrhundert", Siedler Verlag, Berlin 2003, page: 46, 9) G. Hardach: "Industrial Mobilization in 1914-1918: Production, Planning and Ideology", in P. Friedenson (ed.): "The French Home Front 1914-1918", Berg editions, Oxford 1992, pp: 57-88, 10) Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998, 11) N. Stone: "The Eastern Front 1914-1917", Penguin editions, London, 1998, 12) I. Cawood & D. McKinnon-Bell: "The First World War", Routledge 2001, page 46, 13) M. Clarck: "Modern Italy 1871-1995", Longman editions, London 1996, pp: 186-188, 14) F. L. Galassi: "Hanging off the Windowsill: Italy at War 1915-1918", paper presented in Warwick, UK, 8-19 July 2002, page 33. (Data refer to fiscal years 1 April-31 March), 15) N. Stone: "Europe Transformed 1878-1919" Blackwell, second edition 2002.

**TABLE 7: TECHNICAL CHARACTERISTICS-ARTILLERY**

<b>Guns</b> / <b>Howitzers</b> / <b>Mortars</b>	Weight (in kg)	Length of gun (in mm)	Weight shell (in kg)	Maximum range (in meters)	Velocity (shells per minute)
<b>British</b>					
Howitzer 4,5 inches	1,364	1,778	15.8	6,672	4
Gun 60 libr	4,465	4,267	27.2	11,242	2
Howitzer 9,2 Mark-II	16,510	4,318	131.4	12,736	2
Gun 18 libr Mark-I	1,278	2,463	8.4	5,963	8
Train Howitzer 12 in Mark-III	37,185	4,432	339.7	10,364	1
<b>French</b>					
Gun 75mm	965	2,320	7.25	7,500	15 (30 in exceptional cases)
Gun 155mm (Filloux)	10,750	5,920	43.1	16,200	2
Mortar 370mm	30,000	13 (in foot)	1,076 (in lib)	8,820 (in yards)	1 (per 2 min)
<b>German</b>					
Howitzer 10.5 mm. M1916	1,450	2,310	15.6	9,186	4
Gun 13 cm. M1913	5,791	4,725	40.3	14,394	2
Gun 15 cm. M1913	2,200	2,096	41.7	8,497	5
21 cm. (Mörser)	6,680	2,296	11,3	11,100	2
Gun 10 cm. M1917	6,104 (in lib)		39.5 (in lib)	12,085 (in yards)	2
Mortar L-16 42 cm	75,000		2,052 (in lib)	15,500 (in yards)	1 (per 6 min)
<b>Austrian</b>					
M14 (10.4 cm.)	1,200	1,768	14.7	7,800	4
Howitzer 30,5 cm. (M1911)	42,600			13,000 (in yards)	1 (per 6 min)

**Sources:** 1) John Ellis & Michael Cox: "The World War I Databook", Aurum Press editions, London, 2001, pages 301-303, 2) Arthur Banks: "A Military Atlas of the First World War", Leo Cooper, 2004, pages 33, 63, 219-234

**TABLE 8: MAIN CHARACTERISTICS- MACHINE GUNS**

Types	Range (in km.)	Weight (in kg)	Velocity (rounds per minute)	Ammunition (per item)
<b>British</b>				
Vickers MkI	0.303 inches	18.1	450-500	250 rounds
Lewis	0.303 inches	11.8	500-550-600	47 rounds
<b>French</b>				
Hotchkiss	8	23.6	600	24-30 rounds /
Chauchat	8	9.1	250	20 rounds
<b>Italian</b>				
Fiat-Revelli	6.5	17	400	50 rounds
<b>Russian</b>				
Maxim M1910 Sokolov	7.62	23.8	520-580 (500-600)	250 rounds
<b>US</b>				
Browning	0.30 inches	14.97	500	250 rounds
<b>German</b>				
Maxim 08	7.92	26.4	300-450-600	250 rounds
Maxim 08 / 15	7.92	31 (libre)	600	n/a
<b>Austrian</b>				
Schwartzlose	8	19.9	400	250 rounds

**Sources:** 1) John Ellis & Michael Cox: "The World War I Databook", Aurum Press editions, London, 2001, pp. 303-304, 2) Arthur Banks: "A Military Atlas of the First World War", Leo Cooper, 2004, pp. 224-225. n/a=not available

### LESSONS FOR CURRENT AND FUTURE CONFLICTS

The story of the German defence industry during WWI indicates that in terms of economic-industrial mobilization the main emphasis was given to a handful of big enterprises. Thus the role of SMEs (small & medium enterprises has been auxiliary if not marginal). The outcome of this process was that the big size firms had immense profits during the war. To illustrate, the profits of Krupp increased from 31.6m M during 1913-1914 to 33.9 m in 1914-1915, 86.5 m M in 1915-1916 and 79.7 m M in 1916-1917. The profits of DWMF increased from 5.5 m in 1913 to 8.2 m, 11.5 m and 12.7 m during the same years. The profits of Rheinmetall increased from 1.4 m in 1913 to 3.5m, 9.9 m. and 15.3 m respectively.<sup>83</sup>

How are all the above relevant with the current evolution in global defence industry? The first remark that I shall make is that because of the pace of technological change R&D costs have been increasing tremendously from the 1950s until today. To provide just one example from the development of conventional weapons the cost (per unit) for the WWII P-47 fighter of the US Air-Force was just \$100,000. However, the cost for a single F-105 fighter during the 1954-1963 period was \$2.5 million, whereas the development of one F-15 was more than \$10 million. The cost for each aircraft carrier of WWII (Essex class) was \$4.7 million, whereas the cost for the Enterprise (in 1961) was \$451.3 million.<sup>84</sup> Turning to more modern equipment the cost of one F-16/50+ has been \$32m, the cost of one F-22A has been more

<sup>83</sup> See: Gerd Hardach: "Der Erste Weltkrieg 1914-1918", Deutscher Taschenbuch Verlag, 1973, p. 117.

<sup>84</sup> See: Robert E. Harkavy: "The Arms Trade and International Systems", Cambridge Mass, 1975, p. 46.

than \$70m, the cost of one Mirage-2000-5 has been \$35m. Furthermore, the per unit cost of EF-2000 has been \$50-65 million, whereas the per unit cost of Su-27/30 has been \$40-50 million.<sup>85</sup> The point is obvious, technological change is associated with high per unit cost due to high R&D costs. The above “law” will continue to be applicable across conflicts during the 21<sup>st</sup> century. It seems that the lion’s share of war related R&D as well as profits was and will remain across a handful of companies. Paradoxically it seems that this phenomenon is observed with the current conflicts in Iraq and Afghanistan. The defence spending related to Iraq, Afghanistan and other Global War On Terror (GWOT) operations for the 2001-2009 period are demonstrated in the following Table.

**TABLE 9: BUDGET ALLOCATIONS FOR IRAQ, AFGHANISTAN AND OTHER GLOBAL WAR ON TERROR OPERATIONS 2001-2009 (in billion \$)**

	<b>FY01 &amp; FY02</b>	<b>FY03</b>	<b>FY04</b>	<b>FY05</b>	<b>FY06</b>	<b>FY07</b>	<b>FY08</b>	<b>FY09</b>
<b>Total Iraq</b>	<b>0.0</b>	<b>53.0</b>	<b>75.9</b>	<b>85.5</b>	<b>101.7</b>	<b>130.8</b>	<b>141.1</b>	<b>94.8</b>
<b>Total Afghanistan</b>	<b>20.8</b>	<b>14.7</b>	<b>14.5</b>	<b>20.0</b>	<b>19.0</b>	<b>39.1</b>	<b>43.4</b>	<b>55.2</b>
<b>Total GWOT</b>	<b>13.0</b>	<b>8.0</b>	<b>3.7</b>	<b>2.1</b>	<b>0.8</b>	<b>0.5</b>	<b>0.1</b>	<b>0.2</b>

**Source:** Amy Balaso: “The Cost of Iraq, Afghanistan and Other Global War on Terror Operations Since 9/11”, Congressional Research Service, Report for Congress, RL, 33110, submitted September 28<sup>th</sup> 2009, page 13.

From the data of Table 9 we can see that total defence allocations for the Iraq conflict have been \$682.8 billion. The allocations for Afghanistan have been \$226.7 billion, while the expenses related to other Global War on Terror activities were \$28.4 billion. Thus the total expenses have reached the amount of \$937.9 billion, or almost one trillion.

The two main types of costs according to the US Army are the operational costs (related to the payment of military personnel as well as maintenance costs) and the investment costs (related to procurement, R&D, training, construction of military installations). The LOGCAP (=Logistics Civil Augmentation Program) has been awarded in three companies. These are: “Brown & Root Services of Houston”, “Dyncorp”, “Halliburton”. Each company has an annual sum, which vary between, \$5-\$15 billion.<sup>86</sup> Thus an oligopoly of enterprises is gaining the lion’s just like during World War I. The German companies had done a magnificent job, but eventually the war was lost. It remains to be seen if history will repeat it self.

<sup>85</sup> These are fly-away prices excluding ammunition, training etc. They were offered to the Hellenic Air-Force during the late 1990s. See: Nickos Kyriazis & Ioannis-Dionysios Salavarakos: “Defence Procurement in Greece: A Cost-Benefit Analysis of Fighters for the Hellenic Air-Force”, in the volume: “Proceedings of the 10<sup>th</sup> Annual International Conference on Economics and Security”, December 2006, pages: 381-399.

<sup>86</sup> See analytically: Valerie Bailey Grasso: “Defence Logistical Support Contracts in Iraq and Afghanistan: Issues for Congress”, Congressional Research Service, Report for Congress, RL 33834, submitted April 28<sup>th</sup> 2010, pages 2 and 8.

## CONCLUSIONS

The German defence industry during WWI outperformed the industry of the allies, on a single country production basis. One may challenge this by saying that the French industry, became the epitome of allied arsenal. France performed better since the French had lost the critical resources of northern France. However as a counter argument one can state that the US as well as Great Britain supplied the French industry with huge quantities of raw materials. Thus the losses from northern France were balanced. On the other hand with critical levels of supply the German industry should supply not only the armed forces of the Kaiser, but also the other states of the Central Powers.

With limited evidence we can also point out that the structure of the defence industry of the Second Reich was similar to that of monopolistic competition. However in reality during the war years the defence industry acted rather as an oligopoly. A small number of big firms were engaged in massive armaments construction, whereas the SMEs were providing only auxiliary equipment.

The above pattern seems to be repeated nowadays from the US forces in Iraq and Afghanistan. We do not know if they will win or lose the wars, but it is certain that the US and the western coalition has not won yet.

Let us provide some main points which are deducted by the present study:

1. The current study provides an essential contribution to existing research since this is the only study which encompasses both empirical evidence (i.e. vast amount of available statistical figures related to war production), with theoretical elements of economic theory and demonstrate that behind the impressive statistics the German industrial mobilization was a failure since the absence of competition between firms allowed the producers to overcharge prices and deduct high profits at the expense of the taxpayer during the era of war. With the application of monopoly or cartel practices the economic cost of the war skyrocketed, for the German Treasury and the taxpayers. The total economic cost of the war for Germany has been calculated by various sources. To illustrate, Bogart (1920) calculated the direct economic cost for Germany at \$37,775,000,000. Kennedy (1989) provided the estimate of \$19.9 billion (at 1913 prices). Grey & Argyle (1991) provide the estimate of \$58,072 million. Chickering (1998) provides the estimate of \$40,150,000,000. Ferguson (1998) provides the estimate of \$47 billion. Broadberry & Harrison (2005) provide the estimate of \$9.4 billion.<sup>87</sup> Whatever the pecuniary cost it is obvious that this was partially high due to the practice of firm producers to act as a cartel or a monopoly and charge any price that they liked for defence procurement articles. The profits of the German armaments industries, demonstrates this point.

---

<sup>87</sup> See: 1) Ernest Bogart: "Direct and Indirect Costs of the Great War", 1920, pp: 267, 299, 2) Paul Kennedy: "The Rise and Fall of Great Powers Economic Change and Military Conflict from 1500 to 2000", Fontana Press, 1989, page 354, 3) Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume II (1916-1921), page 292, 4) Roger Chickering: "Imperial Germany and the Great War 1914-1918", Cambridge University Press, 1998, page 195, 5) Niall Ferguson: "The Pity of War", Penguin Books, 1998, page 337, 6) S. Broadberry & M. Harrison: "The Economics of World War I: an overview", in the volume: S. Broadberry & M. Harrison (eds.): "The Economics of World War I", Cambridge University Press, 2005, page 28.

2. The above point demonstrates why the research is relevant today. The complete cost of the Iraq and Afghanistan wars is not known, however certain studies provide a picture. To illustrate, Stiglitz & Bilmes (2008) calculate that the direct and indirect costs of the wars in Iraq and Afghanistan are around \$5 trillion for the US economy.<sup>88</sup> According to a different study the cost of the wars of Iraq and Afghanistan are going to exceed the astonishing figure of \$7 trillion.<sup>89</sup> Since in Iraq and Afghanistan the logistical support of the armies is provided by a small number of enterprises we can deduce the conclusion that these will act as the German enterprises and charge high prices in order to maximize profits. The above assertion is documented by Blumenthal (2006) and Anderson (2011). To illustrate Blumenthal (2006) points out that although the Army Corps of Engineers chief objected to a \$7 billion no bid contract awarded for work in Iraq to a specific company she was demoted. Anderson (2011) points out that many US companies working either for the reconstruction of Iraq or for the supply and maintenance of the armed forces have been fined due to misallocation of resources, fraud or corruption. Thus the inefficient use of pecuniary resources by a small number of enterprises is documented in the cases of Iraq and Afghanistan, just like the case of World War I Germany.<sup>90</sup>

3. The implications of the study both theoretical and practical are as follows: The theory of total war, points out that belligerents, which possess more resources (human, financial, industrial), have higher probabilities to win wars. To illustrate, the study of conflicts of the 1800-1849 period demonstrates that in the 88.2% of cases the “strong” prevail over the “weak”. For the period 1850-1899 the figure is 79.5%. For the period 1900-1949 the figure is 65%. The situation changes for the period 1950-1999, where the weak prevail (51.2% of cases against 48.8% of cases where the strong prevail). In total during the period 1800-2003 in the 71.5% of cases the strong prevail over the weak.<sup>91</sup> Thus the only possibility that the weak have in order to win a war is to mobilize their resources more quickly and more efficiently, compared to the strong. This will provide them a window of opportunity for a specific period of time. Of course if tactical errors occur then the advantage will be lost and the outcome of the war will be the defeat of the weak party. It is obvious that in the case of the First World War the Central Powers were the weak party versus the Entente. It is also obvious that the German economic / industrial apparatus failed to maximize the production of war material during the early stages of the war. If the increases of military hardware production had occurred during 1915-1916 instead of 1917-1918 the outcome may have been different.

Let us now turn to the practical implications. Total war involves the participation of the whole of the society directly or indirectly to the war effort. If the civil population does not support the war effort then sooner or later the society will exercise power over the government and the military to terminate the war by any means. Thus social support is

<sup>88</sup> See: Joseph Stiglitz & Linda Bilmes: “The Three Trillion Dollar War”, Allen Lane, 2008, pages 130-131.

<sup>89</sup> See: Neta C. Crawford: “US Costs Through 2013: \$3.1 Trillion and Counting Summary of the Costs for the US Wars in Iraq, Afghanistan and Pakistan”, Boston University 13-3-2013, online source: <http://www.costofwar.org>

<sup>90</sup> See: Sidney Blumenthal: “How Bush Rules”, Princeton University Press, 2006, page 261 and Terry H. Anderson: “Bush’s Wars”, Oxford University Press, 2011, pages 196, 234-236.

<sup>91</sup> See: Ivan Arreguín-Toft: “How the Weak Win Wars. A Theory of Assymmetric Conflict”, Cambridge University Press 2005. For the period 1800-1849 34 conflicts are examined, for the period 1850-1899, 78 conflicts are examined, for the period 1900-1949 43 conflicts are examined, and a similar number is examined for the 1950-1999 period. In total for the period 1800-2003 200 different conflicts are examined.

critical for success or failure. However this support will come only if casualties are low, the economic cost of the war is low and if the cost is equally distributed across society. This last point presupposes that the defence industries will not have excess profits; whereas the individuals will be strangled economically via higher taxes (to finance the war) and high inflation (due to shortage of various consumer goods). If the society realizes that some small elite profits from the war and the majority of people suffers the society will press for the termination of the war effort. This is exactly what has happened in the case of the First World War. The German armistice of November 1918 occurred after an internal rebellion and the same can be said about the wars in Iraq and Afghanistan. The Iraq operation formally terminated in 2013 and the Afghanistan operation will formally terminate during the current year (2014). In both cases popular support for the wars decreased throughout the years and put pressure on the US Administration to terminate the conflicts. It is obvious that history repeats itself...

## REFERENCES

### *1. Archival Sources.*

- Der Todt als Maschinist: der industrialisierte Krieg: 1914-1918: eine Ausstellung des Museums Industriekultur Osnabruck im Rahmen des Jubiläums "350 Jahre Westfälischer Friede", 17 Mai-23 August 1998: Katalog Rolf Spilker, Bernd Ulrich eds. Bramsche: Rasch 1998.
- "Germany and the Second World War" Volume V/II, Oxford, 2003. This is the German official history for World War II but it has some essential data for World War I as well.

### *2. References in English (Books, Book chapters, journal articles, conference papers ).*

- J. Adelman: "Prelude to the Cold War The Tsarist, Soviet and US Armies in the Two World Wars", Lynne Rienner Publishers, Colorado, 1988.
- Anderson Terry H.: "Bush' s Wars", Oxford University Press, 2011.
- Ivan Arreguín-Toft: "How the Weak Win Wars. A Theory of Assymetric Conflict", Cambridge University Press 2005.
- R.B. Asprey: "The German High Command at War", Warner Books, 1996.
- Arthur Banks: "A Military Atlas of the First World War", Leo Cooper, 2004.
- Bernard P. Bellon: "Mercedes in Peace and War", Columbia, University Press, 1990.
- S. Blumenthal: "How Bush Rules", Princeton University Press, 2006.
- Peter Botticelli: "Rolls-Royce and the rise of high-technology industry", in the volume: Thomas C. McCraw (ed.): "Creating Modern Capitalism", Harvard University Press, 1997, pp: 96-132.
- Stephen Broadberry & Mark Harrison (eds.): "The Economics of World War I", Cambridge University Press, 2005.
- E.D. Brose: "The Kaiser's Army", Oxford University Press, 2001.
- Roger Chickering: "Imperial Germany and the Great War 1914-1918", Cambridge University Press, 1998.
- M. Clarck: "Modern Italy 1871-1995", Longman editions, London 1996.
- Hermann Cron: "Imperial German Army 1914-1918, Organisation, Structure, Orders of Battle", Hellion editions, 2006.
- Robert A. Doughty: "Pyrrhic Victory French Strategy and Operations in the Great War", Harvard University Press, 2005.
- John Ellis & Michael Cox: "The World War I Databook", Aurum Press London, 2001.

- Edward Erickson: "Ordered to Die: A History of the Ottoman Army in the First World War", Greenwood press, 2001.
- Michael Epkenhans: "The German Armament Industry and Economic Development, 1870-1914", paper presented in the Workshop: "The Armament Industry and European Economic Development (1870s-1939)", European University Institute, Florence, Italy.
- J. Fear: "German Capitalism", in Th. K. McCraw (ed.): "Creating Modern Capitalism", Harvard University Press, 1997, pages 135-184.
- Gerald Feldman: The Great Disorder. Politics, Economics and Society in the German Inflation 1914-1924, Oxford University Press, 1997.
- Gerald D. Feldman: "Army, Industry and Labor in Germany 1914-1918", Berg, second edition, 1992.
- Niall Ferguson: "Paper & Iron. Hamburg Business and German Politics in the Era of Inflation, 1897-1927", Cambridge University Press, 2002.
- N. Ferguson: "The Pity of War", Penguin Books, 1998.
- P. Gatrell: "Government, Industry and Rearmament in Russia 1900-1914", Cambridge, 1994.
- Martin Gilbert: "The Routledge Atlas of the First World War", Routledge, second edition, London, 1994.
- Valerie Bailey Grasso: "Defence Logistical Support Contracts in Iraq and Afghanistan: Issues for Congress", Congressional Research Service, Report for Congress, RL 33834, submitted April 28<sup>th</sup> 2010.
- Randal Gray & Christopher Argyle: "Chronicle of the First World War", Volume I (1914-1916), Facts on File, 1991,
- Randal Grey & Christopher Argyle: "Chronicle of the First World War", Volume II (1916-1921), Facts on File, 1991.
- Leo Grebler & Wilhelm Winkler: "The Cost of World War to Germany and to Austria-Hungary", New Haven, Yale University Press, 1940.
- P.G. Halpern: "A Naval History of World War I", UCL Press, 1994.
- G. Hardach: "Industrial Mobilization in 1914-1918: Production, Planning and Ideology", in the volume: P. Friedenson (ed.): "The French Home Front 1914-1918", Berg editions, Oxford 1992, pp: 57-88,
- Robert E. Harkavy: "The Arms Trade and International Systems", Cambridge Mass, 1975.
- A.D. Harvey: "Collision of Empires Britain in Three World Wars 1793-1945", Phoenix editions, 1994.
- D. Held & A. McGrew & D. Goldblatt & J. Perraton: "Global Transformations. Politics, Economics and Culture", Polity Press, 2000.
- Holger H. Herwig: "The First World War. Germany and Austria Hungary 1914-1918", Arnold, 1997.
- R. Jackson: "The Encyclopedia of Military Aircraft", Paragon editions, 2002.
- Herbert Jager: "German Artillery of World War One", The Crowood Press, 2001.
- John Keegan: "The First World War", Pimlico editions, London, 1998.
- Paul Kennedy: "The Rise and Fall of the Great Powers. Economic Change and Military Conflict from 1500 to 2000", Fontana Press 1989.
- Martin Kitchen: "The German Offensives of 1918", Tempus, 2001, UK.
- Martin Kitchen: "A Military History of Germany", The Citadel Press, 1976.
- Nickos Kyriazis & Ioannis-Dionysios Salavrakos: "Defence Procurement in Greece: A Cost-Benefit Analysis of Fighters for the Hellenic Air-Force", in the volume: "Proceedings of the 10<sup>th</sup> Annual International Conference on Economics and Security", December 2006, pages: 381-399.
- R. Lewinsohn: "The Profits of War", New York, 1937.



- William Manchester: "The Arms of Krupp", Back Bay Books, London 2003.
- William H. McNeil: "The Pursuit of Power", Blackwell, UK 1983.
- John Mosier: "The Myth of the Great War. A New Military History of World War One", Profile Books, London, 2001.
- Philip Noel Baker: "The Private Manufacture of Armaments", London, 1972.
- Mark Osborne Humphries & John Maker (eds.): "Germany's Western Front 1915", Wilfrid Laurier University Press, 2010.
- R.J. Overy: "War and Economy in the Third Reich", Oxford University Press, 1995.
- Edward Paice: "Tip & Run The Untold Tragedy of the Great War in Africa", Weidenfeld & Nicolson, London, 2007.
- Robin Prior & Trevor Wilson: "The First World War", Cassel editions, London 2000.
- Gary Sheffield: "War on the Western Front", Osprey, 2007.
- A. Speer: "Inside The Third Reich", Phoenix editions, 2002.
- David Stevenson: "With our Backs to the Wall Victory and Defeat in 1918", Allen Lane, London, 2011.
- David Stevenson: "The History of the First World War 1914-1918", Allen Lane, London 2004.
- David Stevenson: "Armaments and the Coming of War. Europe 1904-1914", Oxford, Clarendon Press, first edition, 2000.
- Joseph Stiglitz & Linda Bilmes: "The Three Trillion Dollar War", Allen Lane, 2008.
- N. Stone: "Europe Transformed 1878-1919" Blackwell, London, second edition 2002.
- N. Stone: "The Eastern Front 1914-1917", Penguin, London, 1998.
- Hew Strachan: "The First World War: To Arms", (Volume I) Oxford University Press, 2001.
- Adam Tooze: "The Wages of Destruction. The Making and Breaking of the Nazi Economy", Allen Lane, 2006.
- Clive Trebilcock: "The Vickers Brothers Armaments and Enterprise 1854-1914", London, 1977.
- Ulrich Trumpener: "Suez, Baku, Gallipoli: The Military Dimensions of the German-Ottoman Coalition 1914-1918", in the volume: B. Kiraly & N.F. Dreisziger (eds.): "War and Society in East Central Europe", Vol. XIX, Columbia University Press, 1985, pages 381-400.
- Spencer Tucker: "The Great War 1914-1918" UCL Press, London 1998.
- Martin Van Crevel: "Supplying War", Cambridge University Press, 2004.
- John Walter: "Guns of the Third Reich", Greenhill Books 2004.
- John Walter: "The Greenhill Dictionary of Guns and Gunmakers", Greenhill Books, 2001,
- John Walter: "Allied Small Arms of World War One", The Croowood Press, 2000.
- John Walter: "Central Powers Small Arms of World War I", The Croowood Press, 1999.
- R.J Winklareth: "Naval Shipbuilders of the World", Chatham Publishing, London, 2000.
- D. Woodward: "Armies of the World 1854-1914", Sidgwick & Jackson Limited, UK, 1978.

**3. References in German (Books, Book chapters, journal articles, conference papers ).**

- Heinz-J. Bontrup & Norbert Zdrovomyslaw: "Die Deutsche Rüstungsindustrie", Diestel Verlag, 1988.
- Dietrich Eichholtz: "Geschichte der deutschen Kriegswirtschaft 1939-1945", Band III (1943-1945), Teil I, Munchen 2003.
- Gerd Fesser: "Die Kaiserzeit. Deutschland 1871-1918", published in 2000 by the Landeszentrale für politische Bildung.
- Lothar Gall: "Krupp im 20. Jahrhundert", Siedler Verlag, Berlin 2003.

- Gerd Hardach: "Der Erste Weltkrieg 1914-1918", Deutscher Taschenbuch Verlag, 1973.
- Zdenek Jindra: "Der Rüstungs-konzern Fried. Krupp AG. 1914-1918", initially Ph.D. Dissertation, XCVIII, Charles University Prague, 1983, published as a book, Univerzita Karlova, Praha, former Czechoslovakia (CSSR), 1986.
- Rainer Karlsch & Raymond G. Stokes: "FAKTOR ÖL. Die Mineralölwirtschaft in Deutschland 1859-1974", Verlag C.H. Beck, Munich 2003.
- A. Ruppert: "Militar und Rüstung in der Region Lippe 1914-1945", Bielefeld, 2001.

**4. References in Greek (Books, Book chapters, journal articles, conference papers ).**

- M.V. Creveld: "Command in War", Turikis publications, Greek edition, Athens 2001.
- M. Crouzet: "World History of Civilization", Spyropouloi & Comoudoureas editions, Athens, 1959.
- Ioannis-Dionysios Salavrakos: "Economy and Total War, Vol. I The Case of the First World War (1914-1918)" Athens, Scientific Library series, Kritiki publications, September 1997.
- S.A. Skondras & S.Korovilas: "History of the First World War 1914-1918", Volumes I, II, III, Kekrops editions, Athens, 1969.

**5. References in French (Books, Book chapters, journal articles, conference papers ).**

- Claude Beaud: "Les Schneider "marchands de canons"", Paper presented in the Workshop: "The Armament Industry and European Economic Development (1870s-1939)", European University Institute, Florence, Italy.

**6. Internet sources.**

<http://www.costofwar.org>

-----  
(\* ) Address for correspondence:

Dr. Ioannis-Dionysios Salavrakos,  
Accredited Assistant European Parliament,  
Former Assistant University Professor,  
European Parliament,  
Rue Wiertz 60  
1047 Brussels  
Building / Office: ASP07H 169  
Tel: 0032-(0) 2 2847758,  
Fax: 0032-(0) 2 2849758,  
email: [ioannisdionysios.salavrakos@europarl.europa.eu](mailto:ioannisdionysios.salavrakos@europarl.europa.eu)

This is a modified version of a paper originally presented in the University of Glasgow, Scottish Centre for War Studies, June 24-25 2010.

DISCLAIMER: The current paper reflects private views and it does not reflect the views of the European Parliament.