# War of attrition: Economic warfare between Britain and Gemany in World War II

Mark Harrison and Hans-Joachim Voth*

*Abstract*

For both Britain and Germany, economic warfare was at the core of World War II. We review the efforts of each to strangle the other economically and to pre-empt the other's attempt to do the same. Both countries were tough targets, and neither was brought low by economic warfare alone. Economic warfare was part of the war of attrition and the effects of economic warfare were felt only in combination with attrition on the battlefield. Britain, supported by its American ally was too tough a nut to crack. By contrast, British and Allied economic warfare against Germany largely succeeded. Success came only after far more time elapsed than was originally hoped and after the expenditure of extraordinary and unanticipated efforts, and in conjunction with the pressures brought about by the Allied blockade and the Allied victories on land. Allied economic warfare succeeded by forcing Germany to incur the costs of trying to pre-empt it before the war and, in wartime, to defend against it and adapt to it. We trace the evidence of these efforts and the hollowing out of German resistance that resulted. By 1945 Germany's population had been pushed beyond the limits of adaptation.

Keywords: blockade, strategic bombing, economic warfare, war of attrition, World War I, World War II.

JEL Codes: H56, N44

Acknowledgements: This is a chapter in preparation for *Economic Warfare: Three Centuries of Privateering, Warfare, and Sanctions*, edited by Stephen Broadberry and Mark Harrison. The authors thank all the participating coauthors, Richard Overy, and Duncan Weldon for comments, and Jonas Scherner for advice and help.

* Harrison is from the Department of Economics and CAGE, University of Warwick; Voth is from the Department of Economics, University of Zurich. Both are research associates of the CAGE Centre, University of Warwick, and research fellows of CEPR. Correspondence: mark.harrison@warwick.ac.uk

This version: 16 June 2024

# War of attrition: Economic warfare between Britain and Germany in World War II

In World War II, Britain and Germany waged economic warfare against each other from the first to the last weeks of the conflict. Economic warfare took the form of blockade and bombing. Naval power was the primary instrument of blockade, although often supported from the air, and Britain and its Allies did their best to align Germany's neutral trading partners with the blockade by diplomatic pressure and economic threats. Strategic bombing was the domain of long-range air power.

After the opening moves, World War II quickly became a war of attrition. Attrition was brought about by the simultaneous attack on the adversary's armed forces and the civilian economy. The attack on the armed forces led to attrition in combat and the need to replace the lost personnel and equipment. While the burdens of replacement fell on the civilian economy, attacks on the economy led to further attrition. This further attrition arose directly from military defence against economic warfare, and indirectly from the costs of adaptation to it, which left the civilian economy less able to replace its own losses as well as military losses.

On each side, governments repeatedly burdened the civilian sphere with the cost of battlefield and economic warfare. In the economy, civilians cooperated with each other and with the government to supply the means of fighting power. Extraordinary circumstances called for extraordinary efforts. Somewhere there was a limit to those efforts. The limit was not well defined or readily observed. It was psychological as well as material, and this was captured by worries about civilian morale. Neither side knew where its own limit lay and, for obvious reasons, no government wanted to risk finding out at first hand. Concerns over the limit to civilian sacrifices circumscribed policies long before any actual collapse of morale.

Economic warfare was one of the forces of attrition. Faced by blockade and bombing, each country was compelled to adapt and to bear the costs of doing so. Adaptation involved both defending against economic warfare and mitigating its consequences. Some adaptation could be undertaken in advance, based on anticipation of the likely course of the war. All these responses were costly. The costs, borne first and foremost by civilians, drove each country closer to the limits of adaptation by hollowing out the resources available.

Our chapter is divided into four main sections. In the first, we briefly outline the plans and preparations for economic warfare of Britain and Germany. In the second section, we discuss how economic warfare was conducted. In these first two sections, we give separate consideration to blockade, the traditional instrument of economic warfare, and to its novel instrument, strategic bombing.

The third and fourth sections of our chapter address the adaptation of each country to the economic warfare of the adversary, first Britain and then Germany. We follow this order for two reasons. One is that blockade and bombing interacted in their effects on each country's economy; it would be confusing to discuss adaptation to either instrument out of the context created by the other. And the other reason is that each country's response to being blockaded and bombed was idiosyncratic, so that the country outcomes of economic warfare were entirely different.

Britain and Germany both had allies, and their contributions are discussed where appropriate. Cooperation among Britain, France (until June 1940), the Soviet Union (after June 1941), and the United States (after December 1941) was far closer and more substantial than the very limited coordination of the Axis powers.

## Plans and preparations

The powers' previous experience of blockade, and inexperience of bombing, ensured that the two aspects of economic warfare proceeded quite differently. For blockade, the plans of each side were well prepared and largely anticipated by the other. The Allies, blessed by naval dominance, planned to blockade Germany at sea, more or less on the lines of World War I.

German leaders feared the prospect of Allied blockade. In their minds, the events of 1918 cast a long shadow. Then, amid, spreading malnutrition and a wave of industrial strikes, German morale had crumbled, and revolution had broken out. In public opinion, one important cause was the Allied blockade (Collingham 2011: 25-26; see also Chapter 5). But the fear of another blockade did not act as a restraint. Rather, it drove the National Socialists to place their bet on autarky, to neutralize or pre-empt the effects of a possible blockade by all means at their disposal.

With Hitler in power, Germany prepared for an Allied blockade by two means. One was to make the German economy self-sufficient in three

deficit war materials: iron ore (for steel), oil, and rubber (Overy 1983; Toprani 2020). These measures were far from fully effective; in addition, a major deficit commodity that remained was food (Collingham 2012). The National Socialist authorities supported agriculture and controlled the market, but food self-sufficiency remained beyond their reach. The result was that Germany's economic war preparation became a plan to "feed the war by war." This meant to bring forward the conquest of the region to Germany's East with the intention of diverting its food surplus to German mouths (Dallin 1957). It was an accident of the war's evolution that in 1940 Hitler found himself in occupation of Western (not Eastern) Europe. When the war in the West became stalemated, his attention turned naturally to the East.

As soon as war broke out in the West, both sides put their plans for blockade into effect. The improvisation of the early months of World War I was not repeated. From the start, the Allies exercised the same naval dominance as in the previous war, and this allowed them to replicate the regulation of surface shipping. They largely closed the North Sea and the Atlantic to German vessels and placed neutral shipping under close control.

While German warships made periodic efforts to break out onto the high seas, German leaders anticipated failure on the surface by placing their main reliance on ocean-going submarines. They launched a U-boat offensive with the aim of cutting off Allied trade and isolating the British economy and they pursued it with great seriousness throughout the war.

By contrast, plans for economic warfare from the air did not exist in 1939. This is not because air power was underestimated. Rather, it was overestimated. Public opinion everywhere was convinced of the power of airplanes to attack suddenly, wreck cities, kill very large numbers of civilians, and terrorize the survivors (Overy BW 18-57). For this reason, long-range bombers were valued for their deterrent value more than as a means of victory. In the opening months of the war, both sides were mutually deterred, each fearing to strike the first blow.

**NEW1**When deterrence failed, airmen of both sides turned their attention to offensive operations. What form these should take was far from clear. On the German side, Hitler's inclination was to focus his air force on support of the ground offensives and amphibious landings that would win the victories he sought. He was prepared to consider air operations including the bombing of economic and civilian targets to further these aims but, we will find below, he was naturally sceptical and easily

dissuaded by poor initial results. Later in the war he authorized the V-weapon campaign against British and West European cities under Allied control, but perhaps only when facing defeat on the ground.

On the Allied side, the independent role of air power was taken for granted. Beyond that, a division opened up between the advocates of indiscriminate versus selective or "precision" bombing (e.g. Webster and Frankland 1961, vol. 1: 337-363; Overy 2014: 307-321; Biddle 2015: 495-499). The division was formed by the gap between apparent technological possibilities and limited practical experience. Charles Portal, chief of Britain's Air Staff from 1940, and Arthur Harris, head of RAF Bomber Command from 1942, laid emphasis on the psychological effects of bombing on civil communities. They favoured the relatively indiscriminate bombing of industrial cities and ports, with the aim of "dehousing" and demoralizing Germany's war workers (and incidentally killing them in considerable numbers). By contrast, American air force generals such as Carl A. Spaatz, commander of the USAAF in Europe from May 1942, and Ira C. Eaker, commander of the US Eighth Air Force from December 1942, advocated the precision bombing of selected production facilities. With the right selection, the resulting shortages of key commodities were expected to ripple through the supply of war, inducing a progressive collapse.

The story is sometimes oversimplified. Two qualifications are essential. For one, the British tried precision bombing in 1939 and 1940. Portal saw Germany's oil industry as a particularly attractive target. But the British experience was that precision required daylight, and in daylight aircraft losses were prohibitive. In darkness, nothing smaller could be hit than a city. Learning the same lesson in 1943, the Americans were not opposed to shifting their bombsights when necessary to more feasible but less discriminating targets such as cities (Biddle 2015: 492, 514).

A second qualification, essential in hindsight, concerned the selection of targets for precision bombing. The dominant framework started from the economics of inter-industry linkages created between the wars by Wassily Leontief, whose wartime employment was with the Office of Strategic Services (Bollard 2019: 190-196). Under this influence, American targeting looked for facilities supplying the intermediate goods most in demand for a range of final war products and for military activity. Ball-bearing factories and synthetic oil plants became the canonical cases.

An alternative framework existed, however – one that emphasized the spatial character of inter-industry linkages. The German economy relied

heavily on railways and waterways to distribute coal and ores to its metallurgical, chemical, and engineering plants and to deliver war products to the Western and Eastern front lines which, by 1942, were far from Germany's borders (Mierzejewski 1984: 22-60). The idea of targeting transport linkages also found expert advocates on both sides of the Atlantic, and eventually a high-level British convert in Arthur Tedder, chief of Air Staff from 1940 and deputy Supreme Allied Commander from January 1944 (Mierzejewski 1984: 80-81). **End1**

## The conduct of economic warfare

*The blockades*

At first the Allied blockade of Germany followed closely the lines of World War I (described in Chapter 3). The first instrument of the blockade was "control at sea," which relied on Britain's naval dominance. German warships and flag shipping were driven from the North Sea, leaving only the Baltic for German maritime trade. As exceptions go, the Baltic was far from insignificant because neutral Sweden lay just across it, and also because at this time the Hitler Stalin Pact made the Soviet Union Germany's partner in trade as well as in aggression. On its own, therefore, the Royal Navy could not prevent Germany from trading with allies and neutrals over land and across the Baltic, or from using the neutral neighbours as intermediaries for trade with the rest of the world.

The situation was greatly worsened in June 1940 by Italy's entry into the war and the fall of France. The Royal Navy could no longer control maritime shipping off the entire coastline of Western Europe and North Africa. This sealed the shift from "control at sea" to "control at source," in other words the direct regulation of neutral exports to Germany (Medlicott 1952: 415-417).

The blockade's second instrument, "control at source," drew the Allies into the direct regulation of neutral trade. The underlying purpose was to support Allied economic warfare of Germany, but the means were coercive sanctions on Germany's neutral friends and neighbours, based on Allied naval and commercial dominance, diplomatic pressure, and veiled threats (Golson 2016).

Allied regulation of neutral trade began with the prior certification of vessels and cargoes; only this could avert seizure (not indefinitely, but pending arbitration by an international prize court), so the so-called navicert became the essential prerequisite for neutral shipping to pass the Allied blockade. A related instrument was the capacity to "black-list"

(or sanction) supposedly neutral agents as hostile. A vessel without a navicert, or a blacklisted agent, would be denied market access anywhere in the world under Allied control.

Even these arrangements left room for Germany to benefit from neutral trade. Navicerts and blacklisting could not stop Germany's neutral neighbours such as Switzerland and Sweden from exporting or re-exporting war materials to Germany. Germany's access to Swedish iron ores was a particular source of concern (Milward 1977: 308-313).[1] As in the previous conflict, the answer was sought in war trade agreements with Germany's neutral neighbours. The Anglo-Swedish agreement of 1939 committed Britain to allow Swedish imports up to the prewar level, while Sweden was not to exceed the prewar level of its exports to Germany (and not to re-export goods to Germany that had potential war uses) (Medlicott 1952: 141-152). While the German prospect of victory remained alive, however, British diplomatic pressure was not all-powerful, and Germany was able to import Swedish ores through most of the war.

While the wartime evolution of the Allied blockade of Germany is not without interest, its greatest effects were arguably felt even before the war began. As discussed below, anticipation of the blockade drove Germany's war preparations and channelled its aggression in two directions, overland towards the wheatfields of Ukraine and under the sea around the British coastline.

The German blockade of Britain began in the early weeks of the war, but it did not become fully effective until the fall of France in the summer of 1940. While warships and planes played a role, the main burden fell increasingly on submarines as the war progressed. During the war, Germany produced approximately 1,100 submarines, but a substantial number proved unserviceable (USSBS 1945a: 69). Operational numbers averaged 118 through the war, ranging from a low of 22 in January 1940 to 240 in April 1943 as the Battle of the Atlantic reached its turning point (Davis and Engerman 2006: 295-296).

---

[1] The concern of the time was heightened by the belief that the German economy was fragile, so that its industry would collapse in weeks if the supply could be cut (Salmon 1981). Twenty years after the war, the idea was revived by Karlbom (1965), before being buried by Milward (1967).

The main protection of merchant shipping against submarines was found, as in World War I, in escorted convoys. An advantage was that, while the number of escort vessels required increased with the perimeter of the convoy, the number of vessels protected increased with its square. This advantage of convoys more than compensated for the disadvantage that each had to proceed at the speed of the slowest vessel, increasing time at risk. In practice, unescorted vessels were at much higher risk (Davis and Engerman 2006: 262).

At the beginning of the war, the main Allied and neutral nations (Britain, France, the United States, and Norway) had more than 30 million gross tons of shipping capacity (almost 20m tons were under a British flag). During the war, 21.5 million tons were lost to enemy action, three quarters to submarines (Davis and Engerman 2006: 268-270). More than 30,000 merchant seamen died. From 1943, however, the rate of American shipbuilding was more than enough to cover losses.

Figure 1 shows the monthly dynamics of Allied and neutral shipping losses to submarines against the numbers of German submarines operating at sea. There were three turning points in the campaign. The first two were favourable to the U-boats: the fall of France in mid-1940, which removed an adversary and provided new Atlantic bases; and US entry into the war in December 1941, which greatly increased the number of unescorted shipping targets for submarine attack. The overall situation turned in the Allied favour only in the summer of 1942 after American shipping was placed under an escort regime and Eastern seaboard towns under a blackout.

Figure 1 near here.
Figure 2 near here.

The German ocean-going submarines of World War II were far more capable than those of World War I and the war saw continuing improvements in their range, time submerged, and defensive capabilities. However, the Allies too brought about steady improvements in the organization and technology of anti-submarine warfare, especially from the air, and the gradual extension of air cover from the coasts to the mid-Atlantic (Davis and Engerman 2006: 266-286). As a result, Figure 1 shows, between each of the turning points, the level of sinkings gradually declined. The growing disadvantage of the U-boats is represented more starkly in Figure 2, which captures the attacker's gain (the Allied and neutral ships sunk, relative to the cost in submarines lost. Each advance made by the submariners soon disappeared.

While we will focus below on how Britain adapted to the German blockade, there were implications beyond the British predicament. By 1942 the newly Allied powers were engaged in a cooperative project that had begun with aid from Britain to the Soviet Union in 1941 and now continued, on a much larger scale, with American aid to both Allies (Harrison 1996: 128-154). This increased the value of transatlantic shipping as a target for German submarines.

Economic cooperation among the Allies was essentially the same process as economic warfare among enemies, but with opposite sign (Harrison 2024). Where economic warfare destroyed resources and disrupted supply chains, Allied cooperation created them. Where economic warfare forced societies up against their limits, economic cooperation allowed breathing space. Control of the Atlantic was the essential condition for Allied cooperation. If the German submarine campaign had succeeded in isolating Europe from America, more was at stake than the future of Britain.

*The bombing offensives*

The war's first months were unexpectedly characterized by a mutual reluctance to send bombers against each other's cities. The equilibrium was upset by the Battle of Britain, which ended German hopes of a speedy victory over the United Kingdom. By this point, as well as airfields, each side had begun to raid the other's towns and ports, aiming directly at port facilities and military-industrial targets. In the process each discovered how difficult it was to hit anything with precision. From September 1940, both sides began to raid each other's cities. At this time, each side deployed relatively lightweight bomber aircraft in relatively small numbers. Thus, the first blows exchanged in 1940 and 1941 were relatively minor, with few economic effects and none on fighting power.

More important were the effects on the leaders' thinking. On the German side, Hitler concluded that bombing the British war industries was a waste of effort. His answer was to shift focus to the Eastern front (Overy 1977: 47). By contrast, the British, shortly joined by the Americans, came up with a different answer: to try much, much harder (e.g. Webster and Frankland, vol. 4, 1961: 259-260). The consequences are visible in the tonnage of bombs that each side went on to drop on one other (Table 1). While the tons delivered by each side in 1940 and 1941 were of similar orders of magnitude, a large Allied advantage emerged in 1942 and widened with every year that followed. By the end of the war, even after the deployment of V-weapons against London, Allied bomb tonnage on

Germany had exceeded the German total on Great Britain by more than 25 times.

Table 1 near here

The Allied air offensive evolved over time in several dimensions. Between the fall of France and US entry into the war, British strategy remained caught between over-ambition and lack of means. In his Cabinet memorandum of September 1940, Churchill remarked: "the Bombers alone provide the means of victory": the goal he set for them was to "pulverise the entire industrial and scientific structure on which the war effort and economic life of the enemy depends." But the means available at the time gave no realistic prospect of that.

Several steps led the way to more realistic ambitions. June and December 1941 saw the Soviet Union and the United States enter the war. While the plight of the Soviet Union presented new demands for military aid, the United States offered immense resources. In January 1942, the Washington Conference committed the newly allied British and Americans to open a "second front" on the continent of Europe in 1943. A year later, the Casablanca conference of January 1943committed their bombers to "the progressive destruction and dislocation of the German military, industrial and economic system, and the undermining of the morale of the German people to a point where their capacity for armed resistance is fatally weakened"; but it also postponed the invasion of France to 1944. In the "Pointblank" directive which followed in May, the Combined Chiefs of Staff defined "fatal weakening" as "meaning so weakened as to permit initiation of final combined operations on the Continent" (Webster and Frankland 1961: vol. 4, 273-283).

Over the same period, the means evolved to take the bomber offensive into the realms of feasibility. At the start of 1940 RAF Bomber Command had 438 bombers available, none of them of the heavy four-engined type (BBSU 1945a: 41). By 1943 (all figures are for January) the number had risen to 839, of which 551 were heavy bombers; and by 1945 the numbers were 1,617 and 1,096 respectively. Meanwhile the numbers of heavy bombers available to the 8th and 15th US Air Forces in Europe had grown from 156 at the start of 1943 to 3,115 in 1945. **NEW2**The greater number of the American bombers was offset, however, by lighter bomb loads; this was a consequence of their heavier armament and armour, which turned out to be of less utility than expected. **End2**

The early years provided opportunity to learn. In 1940 and 1941 RAF Bomber Command was focused on attacks on U-boat facilities, the oil industry, and railways centres. The British learned that German air defences made dNylight bombing prohibitively dangerous. At night the bombers could fly more safely, but in darkness they could not find any target smaller than a town (BBSU 1998: 2-9, 53-54). From this grew the British practice of nighttime town raids or "area bombing," set out in a directive of February 1942. The logic was that, given the difficulty of hitting particular facilities, the best way to suppress production was to destroy the workers' neighbourhoods, including housing and essential public services.

**NEW3**Arriving in Europe during 1942, the US Eighth Army Air Force brought with it the belief that night raids were ineffective and a renewed commitment to precision bombing in daylight. The Allied Pointblank directive of June 1943 set the priority for the combined bomber offensive as German fighter production, alongside submarine shipyards and the industries for military vehicles, ball-bearings, and synthetic oil and rubber. The Americans began daylight operations against Germany's ball-bearing and fighter plants in the summer of 1943 but suffered heavy losses. Precision bombing required not only daylight but the suppression of German fighter cover. Until German airspace could be made safe for daylight bombing, the RAF would continue to pound the built-up areas of the industrial towns by night (BBSU 1998: 10-16). This began to change in 1944, when long-range fighters began to cover long-distance daylight raids. German air power weakened, and the scope of Allied operations against Germany widened. The RAF did not stop raiding German towns by night, but it also began to share the effort of daylight raids on German manufacturing and transport facilities.

The British and American approaches to the bombing war never fully converged. The American commitment to precision bombing in daylight was visible whenever circumstances appeared to permit. By contrast the British left the path of area bombing reluctantly and only when pressed (Biddle 2015: 516). Nonetheless, pressure and circumstances were sufficient to bring about a rough convergence of the two national efforts in the closing stages of the war (O'Brien 2015: 321-325).**End3**

Figure 3 shows the main developments of the Allied air offensive. There were two turning points. Through the first quarter of 1943, although already horrifying for those living under it, the bombing of Germany was just a foretaste. The quarterly average of bomb tonnage up to then was just 7 thousand tons. The second quarter of 1943 saw the RAF open the

Battle of the Ruhr, a new campaign against the industrial towns of Western Germany. This was the first turning point, described by Tooze (2006) and Biddle (2015). The quarterly average of bomb tonnage stepped up by an order of magnitude, to more than 50 thousand tons. American daylight raids on industrial targets began at the same time but were curtailed after heavy losses. As a result, the burden of the Ruhr offensive was carried by town raids.

The second turning point arrived in the second quarter of 1944. American bombers gained access to southern Germany from the Italian base of Foccia. The problem of daytime bombing was solved by long-range fighter escorts. As a result, German fighter strength was rapidly degraded, while Allied bombers ranged the length and depth of German air space by night and day. Now the quarterly average of bomb tonnage stepped up by another order of magnitude, this time to 225 thousand tons. While town raids continued to increase in scale, they were more than matched by the scale of attack on other targets: a new carousel of industrial facilities, and a vast campaign against German transportation.

Figure 3 near here
Figure 4 near here

It was only in this final phase that Allied bombing became decisively less costly to the Allies. Figure 4 shows the monthly bomb tonnage dropped by RAF Bomber Command per aircraft lost. For most of 1941 and 1942, the RAF was able to deliver barely 50 tons of bombs for every aircraft lost. In 1943, the number rose towards 100, but did not exceed it decisively until April 1944, rising thereafter to almost 500 tons in the autumn.

## Adapting to economic warfare: Britain

*War production and bombing*

While more could always have been done to prepare for total war, the fact is that Britain entered the war with a relatively large, diversified, and rapidly growing defence industry (e.g. Edgerton 2006: 15-58). Shipyards were beside harbours (Barrow, Birkenhead, Belfast, Glasgow, Southampton). Factories for guns, shells, planes, and military vehicles were in population centres already specialized in engineering and metallurgy (London, the Midlands, Manchester). As a result, there was no shortage of targets for an unfriendly power to aim at.

The prewar growth of the defence industry was governed by competing considerations (Hornby 1958: 203-208; 285-298). Rearmament

presented opportunities for dispersal of war production to the North and West of the country. Even before rearmament became urgent, the government's regional policy of levelling up was one factor promoting greater dispersal. As the threat of war increased, with it arose fear of bombing, and in 1935 London and the East of England were designated a "danger zone" from which war production should be removed.

Unsurprisingly, powerful frictions worked against these seemingly compelling considerations to keep war production where it was. The urgency of rearmament focused decision makers on quick results. Economies of scale and agglomeration would be lost if scattered small factories took the place of large ones and if new capacity was located at a distance from specialized suppliers, habituated workers, and experienced managers. Finally, the increasing range of modern aircraft encroached steadily on the exposed boundaries of the safe areas.

As a result, the main progress in dispersal of the defence industry was limited to a few ammunition plants and ship repair facilities. Many new establishments, including "shadow" factories and dispersal factories, were based around London and the Midlands.

In 1940 and 1941, the Luftwaffe paid considerable attention to the main centres of wartime production and distribution (especially ports). In the year to July 1941 there were 41,000 deaths and a similar number of serious injuries, and a million people were made homeless (Webster and Frankland 1961, vol. 4: 258). The effects on production were modest and, for the most part, transient. Figures for electricity consumption in cities that experienced bombing suggested that economic activity fell immediately by 10 to 25 per cent, but in nearly all cases returned to normal within ten days. Coventry was an exception: after the raids of November 1941, the city took six weeks to recover (Overy 2014: 114).

Other effects were more persistent. Most important was the diversion of major resources to air defence and the emergency services. From the level at the time of the Battle of Britain, the number of fighter squadrons based in the UK was almost doubled. The numbers engaged in air raid precautions and emergency responses rose to 700,000 full-time and 1.5 million part-time personnel by 1941 (Overy 2014: 115).

The personnel and equipment had to come from somewhere. Richard Overy suggests that the result was to divert resources from Britain's war effort in other theatres: the Mediterranean, and beyond. As a result, Britain was less able to resist the U-boat offensive in the Atlantic, German

and Italian aggression in Greece and North Africa, and Japanese aggression in the Far East, and less capable of offensive operations.

Another diversion of resources arose from the immobilization of Britain's east coast ports after the fall of France (Hancock and Gowing 1949: 253, 260). The western ports became congested, forcing ships to lie idle at the docks and so reducing their effective carrying capacity. Once unloaded, the supplies arriving on the west coast had to be rerouted to their destinations, so that the railways also suffered congestion, slowdown, and reduced capacity.

The German bomber offensive diverted British economic fighting power in 1940 and 1941, but this falls short of strategic success. Evidence of strategic success could be direct or indirect. Direct evidence could take the form of resources withdrawn from war production to meet civilian needs that were considered at the time to be more urgent. There is no evidence of that. On the contrary, 1940 and 1941 were years in which war production climbed and the workforce was comprehensively mobilized into uniform and war work.

Indirect evidence of German success might have been signalled by crumbling civilian morale (the "will to make war," as defined by USSBS (1945: 95)) or by indicators of declining health and work capacity of civilians. But there is little to no evidence of either (McKay 2003: 248-265; Overy 2014: 169-196; Todman 2016: vol. 1, 515-524; 2020: vol. 2, 7-16,).

To summarize, the German air offensive imposed serious costs on the British economy but did not put at risk either Britain's military defence or social stability. If the aim was to undermine or destroy Britain's economic fighting power, the outcome was a clear failure.

*Food and the submarine blockade*

Before World War II, Britain imported more than three quarters of wheat and flour, oils and fats, butter, cheese, and sugar (Hammond 1951: 394). The Battle of the Atlantic was hard fought and costly to both sides. By 1942, as Table 2 shows, Britain's quarterly food imports were running at just half the rate of the first nine months (October 1939 to June 1940). The loss of imports was only partly mitigated by a substantial increase in home production. Yet, after a dip at the end of 1939, British food stocks never fell below the pre-war level.

Table 2 near here

The war saw sweeping changes in the composition of the British diet, which became much more vegetarian and considerably more monotonous. The sharpest declines were in the consumption of sugar, fruit, fish and poultry, and tea and coffee, all of which were rationed. The largest increases were in the consumption of grains and potatoes, which were the most important sources of energy. These were never rationed, which speaks to the adequacy of the food supply, if not its variety (Hammond 1951). The result, also shown in Table 2, was that the calories consumed per person remained essentially constant throughout the war, while their distribution was probably somewhat equalized by rationing.

A series of interventions brought this about. Shipping space was rationed. Bulky and perishable foods were to be produced at home. Luxury foods were rationed. Food was subsidized and farmers were paid to plough up grassland and focus on arable crops.

While food supplies remained adequate, the same cannot be said of other consumer products. Civilian supplies of cloth and clothing, fuel and access to transport services, and consumer durables of all kinds were severely restricted (Table 3).

Table 3 near here.

As for health and longevity, adult death rates, which had trended down through the interwar years, rose in 1939 and rose again in 1940. The spike was temporary, however. By 1942 adult mortality was once again below the prewar level and thereafter continued downward along the pre-war trend (Figure 5). Infant mortality followed a similar pattern, spiking in 1940 and thereafter declining. By contrast, the prewar downward trend of stillbirths was barely disturbed by the outbreak of war (Figure 6).

Figure 5 near here.
Figure 6 near here.

It would be rash to conclude that public health posed no issues for the British civilian authorities in wartime. On the contrary, air raids, evacuations, and the unprecedented wartime mixing of the civil population presented stiff tests. Among these (Table 4) were upticks of notifiable infections. Dysentery, pulmonary tuberculosis, and scarlet fever

were persistent; typhoid fever spiked in 1941, then died away. Infectious diseases did not, however, develop into a serious threat.

Table 4 near here.

Living with food rationing, like living under bombardment, occasioned grumbling in queues and in shelters, but did not undermine morale in the form of expectations of victory and willingness to work.

To summarize, Britain survived blockade despite initially relying on foreign sources for nearly two thirds of calories for human consumption. Adaptation to blockade, like adaptation to bombing, was costly. In Britain's case, however, the price of survival did not bear heavily on the war effort. Much grassland was ploughed up for arable cultivation. The agricultural workforce grew by more than 100,000 (or more than 10 percent), but the increase was entirely made up of people drawn out of inactivity. The most significant cost of the turn to self-sufficiency may have been the increased requirement for agricultural machinery: domestic tractor production increased by 250 percent from 1938 to 1943 (CSO 1995: 46, 67, 176). The gain was the shipping space (illustrated in Table A) saved by the turn to home production and consumption of bread and potatoes. Olson (1963: 128) put the cumulative wartime saving at 50 million tons, or nearly two years of peacetime non-oil imports.

Other countries that entered the war nearly or entirely self-sufficient struggled and sometimes failed to feed their populations. They failed because they were poorer at the outset, and so began the war with fewer inessential uses of food; or because their economies were insufficiently integrated, so that wartime shortages could not be mitigated by efficient substitutions; or both.

## Adapting to economic warfare: Germany

*Pre-empting blockade*

As already discussed, German leaders prepared for an Allied blockade before the war. They aimed for self-sufficiency in the main deficit war materials: iron ore, oil, and rubber. But self-sufficiency in food on the territory at their disposal was beyond their reach. Instead, they planned to feed Germans at war by the early conquest of the region to Germany's East and the diversion of its food surplus to Germany.

Table 5 here

Conquest yielded major resources for the Germany economy, for which the figures given in Table 5 represent a lower bound. Measured at prewar prices, the annual volume of net imports reached at least 20 billion in 1942 and 1943, representing 15 per cent of Germany's GNP in those years. A major surprise was where they came from—not Eastern Europe, the colonial prize that National Socialist thinkers had greedily eyed for decades. In 1943, 70 percent of German revenues from the major channel of exploitation, the "occupation costs" that Germany levied on its occupied territories, came from Western Europe. More than 40 percent came from France alone (Abelshauser 1998: 143). In the same year, taking into account all the varied channels of exploitation, France contributed resources equal to 9 percent of German GDP (on the basis of prewar exchange rates) (Milward 1977: 140). Klemann and Kudryashov (2012: 99) estimate the net wartime contribution of occupied and "dependent" Europe to the German war economy at RM93.6 billion, a sum of similar order to one prewar year of Germany's GDP during prewar rearmament. But, of that sum, only RM9.3 billion, or one tenth, came from the occupied East, with another RM8.9 billion from the dependent countries of northern and eastern Europe.[2]

The Eastern territories made a much larger contribution to Germany's war economy in the form of labourers. By 1944, one in five German civilian workers in industry, transport, and agriculture, was a foreigner (Abelshauser 1998: 161). This too was a complete surprise: a war designed to subjugate or kill Europe's undesirable foreigners brought more than 7 million of them (including 1.9 million from former Soviet territories and 750,000 prisoners of war) into the heart of Germany.

Despite the additional resources made available by conquest, German civilians were increasingly exposed to the pressures of war mobilization, blockade, and bombing. By 1943 real civilian consumption in Germany was already 20 percent down on its 1939 peak (the figures in Tables 3 and 5 agree on this despite their different coverage). In early 1943, Germany's colonial sphere reached its maximum extent, after which it began to shrink. Returning soldiers had to be fed at the expense of the homeland instead of the colonies. By 1943, moreover, Allied bombing was starting to drive Germany's aggregate production below its full potential. The German authorities' efforts to protect war production from the effects

[2] The sum of RM8.9 billion is based on summing the subtotals provided for Albania, Bulgaria, Croatia, Finland, Hungary, Romania, and Slovakia.

of bombing thereby shifted the pressure into the civilian sphere. The outcome was a continuing decline in consumption levels.

The ultimate failure of German plans to pre-empt the Allied blockade by war prompted W. N. Medlicott (1959: 646), the official historian of the blockade, to conclude (after two volumes and more than 1,400 pages):

> Fear of the consequences of the blockade played a part in drawing Germany into the Russian adventure and the two-front war which ultimately proved so disastrous for her; perhaps one could say that in this sense the fear of blockade may have been more important than the blockade itself in bringing her to ultimate defeat.

*War production and bombing*

**NEW4**The salient fact of the German war economy was the growth of war production despite the suffocating pressure of relentless blockade and bombing. The index of war production calculated by the statistician Rolf Wagenführ showed a threefold increase from the first months of 1941 to the summer of 1944. The "production miracle" made a mockery of efforts made at the time and afterwards to find a close and contemporaneous link from Allied bombing to the German war effort.

The success of German war production should not be taken entirely at face value. There were elements of "mirage" in the "miracle" (Scherner and Streb 2016). The index was designed for a purpose – to make minister of munitions Albert Speer look good. It concealed occupied Europe's substantial contribution of materials and components for German war industry. It emphasized the growing supply of "big ticket" items while the quality of materials, the availability of spare parts, and service reliability declined. Still, the achievement was real to a considerable extent. Germany could not have resisted Allied military power for long without the 35,000 tanks and 65,000 warplanes produced from 1942 to 1944.**End4**

The Allied air offensive did not prevent Germany's production miracle. Its contribution was to force Germany to defend against the bombers and adapt to continuous bombing. In this section we outline the growing burdens of defence and adaptation. In the following section we show that these burdens gradually depleted civilian resources, so that the German economy eventually encountered the limit of its adaptive capability.

The costs of defence alone were many and heavy. The first requirement of air defence was fighter planes, and of the 93,000 military aircraft that Germany produced after 1941, more than half were fighters. This

compares with just one quarter of the much smaller number built in 1939 and 1940 (USSBS 1945b: 276). Moreover, the needs of air defence in the West stripped the German Army of its air resources in the East. From 1942 more fighter aircraft were deployed in the West and over Germany and, from September 1943, more aircraft of all types (O'Brien 2015a: 290-291). As a result, Soviet cities did not face a major bombing offensive and the Red Army did not face an air-dominant adversary.

In addition to aircraft, Allied air raids also drew German labour resources and armament into air defence and bomb repair. More German troops served in air defence from 1943 onwards than in Stalingrad; more German aircraft were lost to allied air attack and in the air battles over Germany than to any other cause from 1942 onwards. Albert Speer recalled that German air defence in 1944 required proportions of Germany's output of armament, heavy ammunition, and optical and electronic products varying from one fifth to one half. He put the numbers engaged in air raid precautions and bomb repair in 1944 at 1 to 1.5 million (Webster and Frankland 1961, vol. 4: 381, 393-394; for similar figures see USSBS 1945b: 40).

The need to defend against Allied bombing contributed to the attrition of German resources, but it is important to remember that the Allies also suffered attrition. Both sides lost around 40,000 aircraft. Plane for plane, the Allies lost more aircrews and more valuable machinery. If this was a war of attrition, the Allies' advantage lay in their greater economic capacity to sustain losses.

In addition to the costs of defence, Germany also had to adapt and to pay the costs of adaptation. To the Allies, the adaptability of the German economy was largely unforeseen. The canonical case is the 1943 raids on Schweinfurt where Germany's ball-bearing factories were concentrated. Any loss of ball bearings was expected to devastate military machine building. The attack, carried out in daylight at very high cost, destroyed up to half the existing capacity. Yet "there is no evidence that the attacks on the ball-bearing industry had any measurable effect on essential war production" (USSBS 1945a: 6).

It was basic to the advocacy of bombing such "weak links" that the adversary's economy was rigid and unable to flex under attack. Mançur Olson (1962) later showed how Germany's war effort adapted quickly to the blow: by a ripple of economizing and substitution. Before the Schweinfurt raids, Germany's ball-bearing supplies were already more than adequate, which meant large inventories and many inessential uses.

In the face of sudden shortage, it was not difficult to concentrate remaining supplies on war production where they were most needed, while substituting other types of bearing where possible and doing without where necessary. In other words, the German war economy retained considerable slack until 1944 and the slack facilitated adaptation to the combined impact of blockade and bombardment.

While taking up slack helped with adaptation in the short term, there was also the creation of new capacity. Allied bombing is thought to have destroyed one sixth of the industrial fixed capital stock in the future zone of British-American occupation. But damaged capacities could be quickly rebuilt – and not only rebuilt but augmented on a surprising scale. By 1945 the gross value of fixed industrial assets in West Germany was 20 per cent larger than in 1936 – and one third of this gross value was less than five years old (compared to only 9 per cent in 1935) (Abelshauser 1998: 167-168).

But the new capital created in wartime was not as productive as the capital it replaced, partly because it was dispersed away from existing industrial centres to reduce vulnerability to repeated raids (Overy 1994). In the case of the aircraft industry, plans called for the construction of three million square metres of new space – much of it underground (only 200,000 square metres were completed by the war's end). Dispersal worked against concurrent efforts at cost-cutting through rationalisation and centralisation. German sources estimated large production losses from this alone – for example, up to half of the potential supply of Messerschmitt fighters from the summer of 1943 to early 1944 (O'Brien 2015a: 78). The dispersed facilities were also more exposed to disruption of railway transportation (USSBS 1945b: 158-159), so they had to carry larger stocks (Overy 1994: 373).

The heavy costs of new industrial construction had to be taken from somewhere. At first, they came from the remaining reserves of civilian consumption. As the war progressed and civilian surpluses dwindled, the risk would arise that more new facilities could be built only at the expense of new war production.

**NEW5** There was another side to dispersal, one that posed other risks. This was the scattering of the workforce following Allied air raids. While the bombers struggled to target industrial sites with precision, they came to excel at laying waste the employees' neighbourhoods. By the end of the war, two fifths of the urban housing stock of Western Germany and West Berlin had been destroyed. At the same time, while the war witnessed an

acceleration of industrial construction, residential investment came to a standstill. At the war's end, the shortage of urban dwelling units stood at 4.3 million Because of this, German urban districts were depopulated, losing 2.3 million inhabitants by 1946 (compared to 1939). As Vonyo (2012) has shown, the housing shortage became a major drag on industrial recovery that persisted for years after the war. It seems likely, therefore, that the callous expedient of "dehousing" the workers, with or without causing their deaths, was an effective way of disrupting the German urban economy. **End5**

As for how German war production and fighting power adapted, or failed to adapt, to Allied bombing at later stages of the war, there are numerous accounts. The sources fall into two categories: insider estimates found in contemporaneous German documents or reported afterwards by German officials to Allied interrogators; and independent estimates constructed afterwards by the Allied bombing surveys (USSBS 1945a; BBSU 1998).

An advantage of the insider accounts is that they are rich in narrative. On the other side, it is hard to identify any German source with a clear commitment or other reason to tell the truth. Many insiders had reputational incentives either to blame others for difficulties in war production or to boost their own achievements. Nor is it easy to see how they could be audited today. By contrast, the explicit mission of the Allied postwar survey teams was to reach unbiased conclusions. This does not entirely exclude a role for war experiences and service rivalries to bias findings. The British team, much smaller than the US team, was led by Sir Solly Zuckerman, a respected scientific adviser, but not a disinterested party: in wartime he was Tedder's ally in advocating the bombing of German transportation, and was responsible for the wartime plan to target the railways of occupied France.

Both Allied reports presented and deployed much data. For causal inference they relied considerably on narrative and judgement. However, they introduced two methods that offered a firmer basis for identifying causation: differences-in-differences and the construction of counterfactual series. For reasons of space, we focus on these.

Both Allied teams exploited variations in the intensity of bombing across German towns to estimate the effects of town raids (shown in Table 6). The Americans estimated losses of total ("Reich") production year by year from a sample of ten cities. Based on the known destruction of these towns and their contributions to industrial production, the loss of

production was shown to have reached 2.5 percent in 1942, 9 percent in 1943, and 17 per cent in 1944.

Table 6 near here

This was the loss of total output, but it stopped short of finding by how much the authorities were able to protect war production. The British team filled this gap. They compared 21 towns that were heavily bombed to 14 that were largely untouched. Monthly data by town and by industrial branch from April 1943 to June 1944 showed that total output rose everywhere over the period, but in the bombed towns it fell short of the control group by 13.7 percent. The war production lost through bombing was much less, however—only 6 per cent, and the loss diminished over time. This suggested that "with increasing experience of air attack, the Germans became more skilled at diverting the effects of air attack onto the civilian sector of industry" (BBSU 1998: 95). Generalized to Germany as a whole, these findings suggested modest losses of overall war production (Table 4 again).

These findings are limited to the effects of area raids, which became a much smaller proportion of the total effort in 1944. The effects might be understated, however, because the method of differences-in-differences necessarily excludes spillover effects on the economy as a whole.

A more comprehensive picture emerges from the efforts of the British team to construct a counterfactual series of potential war production. They estimated potential output (or capacity) of every plant in every specialized branch of German war industry quarter by quarter through the war and aggregated each sector up on the same basis as Wagenführ's index of war production.

Figure 7 near here

Comparison of actual and potential war production (Figure 7) shows two turning points. One is marked in the second quarter of 1943, when German war production first paused its growth and began to fall short of potential. Another is marked in the third quarter of 1944, when German war production peaked, turned down, and began to fall absolutely.

The figure provides the basis of a conjecture. The bombing war can be separated into three phases. In the first phase, Allied bombing had no effect on war production: Germany's civilian economy was fully able to adapt and accept the sacrifices required to protect the war effort. The first

phase ended in the spring of 1943. In the second phase, the loss of production was no longer zero, though it remained relatively small. Civilian adaptation was now partial: most losses of war production could be made up. This second phase ended in mid-1944. In the final phase, civilian adaptation reached its limit, or failed, so that all the damage done by bombing was reflected in the progressive collapse of war production. We look at the evidence on this conjecture, considering each turning point in sequence.

The idea that Allied bombing first forced German war production below its potential in the spring of 1943 is broadly consistent with the BBSU differences-in-differences estimate of the effects of town raids (Table 6). It is also consistent with narrative accounts of the campaign against the towns and dams of the Ruhr district from March to July 1943 (Tooze 2007: 596-598; see also USSBS 1945b: 146; Biddle 2015: 501-503). O'Brien (2015a: 298) tells another story that begins with the bombing of Germany's main aluminium processing plant in Ludwigshafen, far from the Ruhr and reverberates through the ongoing dispersal of the aircraft industry. This story is different in substance but consistent in timing.

What triggered the progressive collapse of German war production? The collapse began at about the same time that Allied forces on both sides of Germany approached the frontiers of the Reich. To control for the effects of territorial loss, it was necessary to account for them separately in the series for potential war production. As Figure 7 shows, potential output on the territory under German control began to turn down in the first months of 1945; the collapse of war production began earlier and proceeded more rapidly than could be explained by lost territory.

Figure 9 here

The BBSU offered a more consistent explanation of the final collapse in the transportation campaign. The attack on German transport (railways, canals, and bridges) began in the early months of 1944. It intensified in September as Allied control of France was consolidated, eventually taking more than a quarter of the overall Allied bombing effort (Mierzejewski 1984: 102-161). By the use of differences in differences, the British team showed a causal effect of bombing on German railway shipments. Monthly data for 31 railway districts through 1944 showed a precipitate decline of railway shipments that began in August (Figure 8). The decline was accounted for by the 23 districts that were attacked from the air. Districts that were not attacked showed no loss of performance. Thus, the attack on the railways was effective. Finally, the disruption of the railways could

be linked to the decline of war production. Over the ten months up to the end of the war, the decay of German war production appeared to respond to the decline of railway shipments with a lag of one or two months (Figure 9). The inference was that the transportation campaign had at last pushed Germany's war industries up to and over the edge.

Figure 8 here
Table 7 here

Table 7 summarizes the conjecture. In phase 1 of the bombing campaign, Allied bombing of German economic targets ran at 7 thousand tons per quarter, of which one thousand were dropped on transport facilities. Germany's economy was fully able to adapt. In the second phase, the intensity of Allied bombing rose to 81 thousand tons per quarter, of which transport accounted for 27 thousand. In the summer of 1943 German war production stagnated and fell significantly below potential for the first time. When growth resumed, potential output was not regained. Adaptation to Allied bombing was now incomplete, with small but significant quarterly losses of 16 index points. In the final phase, Allied bombing increased again, averaging 285 thousand tons per quarter and 113 thousand tons on transportation. This was beyond the limit within which the German economy could adapt. With quarterly losses reaching 123 index points per quarter, war production began an irretrievable collapse.

Why was the attack on German transportation effective when all else seemed to fail? On this interpretation, when every railway interchange, canal, and bridge had been destroyed, every supply chain was broken. When nothing could move, production stopped, and military resistance also came to an end (O'Brien 2015: 349-357).

*Limits of civilian adaptation*

The purpose of economic warfare was to force the adversary to incur the costs of resistance to a point where further adaptation became impossible. Did the Allies succeed in pushing Germany to the limit? This can be judged from available measures of nutrition, morbidity, mortality, and morale of the German population.

Nutritional standards were already problematic for the mass of German people before war broke out. Under prewar rearmament, according to Baten and Wagner (2002), mortality failed to improve in Germany at rates observed elsewhere in Europe in the interwar years. The immediate reason was the greater prevalence in Germany of infectious and parasitic

diseases associated with poor nutrition of the urban population. Behind the poor quality of food supplies to towns and cities lay the pressures of rearmament, price controls, and the resulting disintegration of the German food market. Even before the war, German consumers were already making a down-payment on the price of their leaders' war ambitions.

The German authorities introduced food rationing for most people on the eve of war. These arrangements were both more and less comprehensive than those made in the United Kingdom. They did not apply to the non-agricultural population, because farmers and farm workers were considered to be "self-sufficient." But they also covered a wider range of foodstuffs, including bread (from the start) and potatoes (eventually); these were never rationed in the UK.

As Table 8 suggests, the energy and protein content of German rations for a working family was adequate at first, even if measured against the rather poor standards of the prewar years. It then declined in steps that were particularly marked in April 1942, May 1943, and October 1944, ending at a level that was altogether inadequate.

Table 8 here.

Table 9 offers a more granular picture that distinguishes between energy and proteins. In wartime, at least outside prisons and concentration camps, workers performing heavy labour and children were somewhat protected. Heavy work attracted more energy and proteins than regular work. In proportion to their body weight, older children were assigned more calories and younger children were given more proteins. The result was that the entitlements of those employed in heavy work that was prioritized for the war effort declined at half the rate of others. By the end of 1944, those engaged in "normal" work had lost up to 15 percent of their calories and almost one-quarter of their protein intake – more, if we consider the quality deterioration that remains unaccounted for.

Table 9 here.

These considerations applied to the principally urban rationed population. They did not hold in the countryside, where "self-sufficient" households enjoyed a substantial advantage (Buchheim 2010: 315).

For town dwellers, the significance of nutritional deficits was cumulative. An SS report of 1943 on the condition of intellectual workers, who lacked

access to the ration supplements for "heavy" work, referred to "severe fatigue, lack of concentration and greater irritability," associated with significant weight loss since the war began (Buchheim 2010: 322).

A useful strategy for urban residents was to trade illegally for the food surpluses of the "self-sufficient" farmers. This helped to increase the food available in towns. But it also impeded the war effort. The black market increased the farmers' incentive to hide their produce from government procurement officials whose job it was to secure food for the war effort and to meet ration entitlements.

The growing deficiency of food rations was not just debilitating. It was also demoralizing. Ration cuts tended to follow military setbacks, which undermined the regime's propaganda of the inevitable victory. Caught between the increasingly urgent needs of the war and the rising resentment of urban consumers, the attitude of the regime to the black market vacillated, sometimes tightening the rules and easing up on enforcement at other times (Buchheim 2010: 311, 314).

Where else should we look for evidence of the limits of adaptation? In the work of Baten and Wagner (2002), increased susceptibility to infectious and parasitic illnesses was a product of persistent undernourishment. Table 10 compares the incidence of a range of the notifiable diseases in wartime Germany to other places and times. In World War II, German civilians experienced a wave of morbidity that was especially marked for diphtheria, pulmonary tuberculosis, and scarlet fever. For diphtheria and scarlet fever the burden was heavier than in World War I (the incidence of tuberculosis cannot be compared). For the latter illnesses, Germany also suffered more widespread infections than the United Kingdom in World War II (Table 4). The British authorities struggled to contain TB, however, and also dysentery to some extent.

Table 10 near here

Eventually, German civilians began to die. In 1943 (as Figure 10 indicates), they died no more frequently than in England and Wales. After 1943, there are no more statistics for Germany as a whole. But the Bavarian authorities' records through the remaining war years have been kept. They show that mortality rose sharply in 1944, and again in 1945 (but most of that year fell after the German surrender). In the Bavarian countryside in 1944, the crude death rate rose from 127 to 145 per 10,000. In Bavarian towns, the increase was greater, from 122 to 191—and 1945 saw further increases. Infant mortality rose in Bavaria in 1944

and 1945, and also in Germany's-major cities (Figure 11). Heightened morbidity and mortality in the last year of the war point clearly to a critical deterioration of the conditions of civilian life.
Figure 10 near here
Figure 11 near here

Finally, we address the issue of civilian morale. There is no doubt that Allied bombing and growing food shortages weakened civilian support for National Socialist leadership and war aims. Based on analysis of official records, secret Gestapo reports, captured civilian correspondence, and interrogations, the US Strategic Bombing Survey (1945a: 95-97) offers a range of stylized facts. Bombing directly affected more than 25 million German civilians, or one third of the total population. The experience of Allied bombing increased the desire for an end to the war, willingness to surrender, and distrust in leaders. These feelings were increased among Nazi party members just as among non-party people, although from a lower base. They were increased by inadequate air raid precautions and poor access to shelters. (They were also increased by becoming personally better informed about what to expect.) Everyone found the experience frightening, and night raids were feared more than daylight raids, but the subsequent disruption of public services was more important as a source of lasting demoralization.

These findings would not have surprised Nazi officials. Internal documents of the time show intense concern for the state of civilian morale and the impact of bombing raids on how citizens rated the Nazi leaders, their competence, and the value of their war aims (USSBS 1945a: 97-98). Bitter jokes soon circulated, contrasting the boasts of leading Nazis like Hermann Göring (head of the Luftwaffe) with the devastation visited on German cities during the second half of the war.

Following the devastating raid on Hamburg in the summer of 1942, party officials were openly confronted by outraged citizens. Many took to hiding their party insignia; citizens stopped using the obligatory greeting "Heil Hitler." When Speer confessed to his diary his fear that a few more attacks like Hamburg would finish Germany, he was thinking mainly about civilian morale. Fear of collapsing support for the regime meant that support for bombed-out civilians became a priority. Special Air Raid Damage Staffs were created to repair buildings (Overy 2014: 437). Furniture and civilian textiles were produced at much higher rates than would otherwise have been the case, to provide replacements for Germans who had lost their home—a use of resources that suggests civilian morale was becoming seen as a top priority.

A particular (and well-known) finding of the American bombing survey was "diminishing returns": those who had experienced very heavy bombing did not show worse morale than those who had lived through bombing of lesser intensity, measured by bomb tonnage on a community or the share of homes destroyed (USSBS 1945a: 96). By implication, if the morale effect of bombing is considered in isolation, "light" bombing of a community (6,000 tons, or the destruction of 20-39 per cent of housing) was as effective as heavy bombing (30,000 tons, or 60 to 80 percent of housing destroyed).

None of these findings should be considered fully robust, however, because of the neglect of factors that might lead to selection biases and spurious correlations and because of lack of attention to standard errors.

Did morale matter? As the American survey notes, government documents of the time "consistently assert that air attacks were undermining morale and producing defeatism, but they usually claim that no matter how the civilians thought and felt, their behaviour showed no active opposition to the war . . . depressed and discouraged workers were not necessarily unproductive workers" (USSBS 1945a: 97).

This conclusion is undermined by recent investigation using new data and modern methods. Adena et al. (2021) measure civilian morale by the frequency of treason trials for anti-Nazi resistance, and military morale by the shootdown rates of ace fighter pilots. Anti-Nazi resisters and ace fighter pilots exemplify the extraordinary efforts that can make a difference in war. The study of civilian morale is based on a sample of 911 cities, of which almost half were bombed at least once. A finding is that the bombed cities accounted for nearly all (95 per cent) of resistance episodes. As Figure 12 shows, the background risk of an episode starting in a city in a month without bombing was just 2.1 per cent, but it shot up to 19.7% in the month a city was bombed.

Figure 12 near here.

With regard to military morale, the bombing of an ace fighter pilot's home town promptly and persistently reduced their subsequent shootdown rate; repeated home-town bombing magnified the damaging effect. Fighting men were kept in touch with the catastrophe engulfing Germany's towns and cities not only by occasional home visits but by more frequent letters from home and by emergency postcards sent by those made homeless.

In contrast to the USSBS findings, Adena et al. (2021) show that bombing did stimulate active civilian opposition, evoking extraordinary efforts against the war. Bombing also reduced military productivity, by damaging soldiers' combat motivation. Nonetheless, it remains the case that most civilians did not engage in organized resistance, and most soldiers fought on doggedly until the end of the war.

The same research finds that bombing was not the only way to lower German civilian morale. Access to BBC radio news, although not significant on its own, was a complement to Allied bombing: each augmented the effect of the other in stimulating resistance. Was the mix optimal? Probably not. BBC broadcasting was much cheaper in lives and resources than Allied bombing.

The morale dimension of bombing also led Germany into its single most ambitious armaments programme, costing RM2 billion—the V (for "Vengeance") weapon program. The V weapons absorbed a share of German resources equivalent to the Manhattan Project in the United States. As postwar testimony made clear, they had little economic or military effect. Nor were they intended for that purpose; their rationale was to terrify the Allied populations, and to shore up domestic morale at home, heavily dented by Allied bombing (O'Brien, 2015: 335).

To summarize, when the supply of war was attacked, protection of the war effort required a shock absorber. The civilian economy was supposed to absorb the shock. Civilians were expected to adapt by accepting substitutes and tightening belts. This would release resources to fill the gaps in the supply of war. The evidence suggests that by 1944 the German household sector was reaching the limit of its adaptability. Nazi fears for a collapse of morale also limited the resources taken from the civilian sector. It could not be allowed to or could not absorb further shocks.

## Conclusion

> There will come a time . . . when the effects of economic war will begin to multiply themselves . . . failure accumulates, battles are lost, wars are lost; and in that ultimate breakdown the effects of economic war will be completely merged with the phenomena of defeat (Vickers 1943: 21-22).

Economic warfare was a crucial dimension of World War II for both Britain and Germany. Each attempted to strangle the adversary economically and tried to pre-empt the other's attempt to do the same.

Both had prepared for a repetition of World War I at sea – Germany through an extensive autarky programme before 1939; Britain by maintaining a large navy to ensure dominance on the seas. Neither was prepared for the air war that followed 1939.

Germany and Britain were tough targets for economic warfare. Neither country was brought low by economic warfare alone. Economic warfare took time to implement and more time for its effects to ripple through the adversary's economy and for the adversary to run out of resources. The attrition arising from economic warfare was felt only in combination with attrition on the battlefield. Britain, with support from its American ally was too tough a nut to crack. Germany lacked time (and its leaders lacked patience) for economic warfare against Britain to succeed.

By contrast, British and Allied economic warfare against Germany largely succeeded. It succeeded only after much more time elapsed than was originally hoped and after the expenditure of extraordinary and unanticipated efforts to build a bomber force of thousands and to replace losses measured in tens of thousands of planes and more than a hundred thousand of aircrew lives. And air attack succeeded only in conjunction with the pressures brought about by the Allied blockade and the Allied victories on the Eastern front, in the Mediterranean, and in France.

Allied economic warfare against Germany aimed to weaken its war effort through the denial of resources – by destroying output or the means of production. The results of the air offensive before 1944, measured by the undermining of the German war effort, were imperceptible until the spring of 1943. They still disappointed through the summer of 1944, reducing German war production by no more than a few percentage points. They became fully effective only in the autumn of 1944 with the intensifying attacks on oil plants and on railway, bridges, and canals.

Allied economic warfare succeeded by forcing Germany to divert resources, economic and military, before the war and during it. Before the war, the fear of blockade drove Germany to bid for autarky, undertaking costly investments in domestic iron ores for steel and in synthetic oil, and rubber. Once the war began, the same fear spurred German ambitions to seize the food-surplus regions to the East. But, instead of freeing Germany from the fear of blockade, the Eastern front became a sink for German military power. Meanwhile the Combined Bomber Offensive forced Germany into a widespread dispersal of war factories that disrupted production and reduced the effectiveness of capital investments. At the

same time air defence of the homeland acquired higher priority than the pursuit of victory in the East.

To protect its war effort from the effects of economic warfare, German leaders sought to adapt by shifting the costs of defence and adaptation onto the civilian sphere. While the German war effort could be expanded in this way for much longer than Allied planners hoped, behind the scenes civilian resources and reserves were gradually depleted. German leaders understood that there was a limit to this process. The long shadows of 1918 limited the hardships that the Nazi regime felt it could impose on the civilian population. Civilian production stayed higher for longer to stave off the morale effects of Allied bombing. But the point arrived came where the losses, not only from economic warfare but from attacks on every front, could no longer be made good by civilian sacrifice. Now the damage rebounded back onto the war effort, which suddenly weakened and began to collapse.

## References

Abelshauser, Werner. 1998. Germany: Guns, Butter, and Economic Miracles. In The Economics of World War II: Six Great Powers in International Comparison, pp. 122-176. Edited by Mark Harrison. Cambridge: Cambridge University Press.

Adena, Maja, Ruben Enikolopov, Maria Petrova, and Hans-Joachim Voth. 2020. Bombs, Broadcasts and Resistance: Allied Intervention and Domestic Opposition to the Nazi Regime during World War II. CEPR Working Paper no. 15292. London: Centre for Economic Policy Research.

Baten, Jörg, and Andrea Wagner. 2002. Autarchy, Market Disintegration, and Health: The Mortality and Nutritional Crisis in Nazi Germany, 1933–1937. Economics and Human Biology 1: 1–28.

BBSU (British Bombing Survey Unit). 1998. The Strategic Air War Against Germany, 1939-1945. Report of the British Bombing Survey Unit [declassified in 1956]. Introd. by Sebastian Cox. London, Frank Cass.

Biddle, Tami Davis. 2015. Anglo-American Strategic Bombing, 1940-1945. In The Cambridge History of the Second World War, vol. 1, 485-526. Edited by John Ferris and Evan Mawdsley. Cambridge: Cambridge University Press.

Bollard, Alan. 2019. Economists at War: How a Handful of Economists Helped Win and Lose the World Wars. Oxford: Oxford University Press.

Buchheim, Christoph. 2010. "Der Mythos vom 'Wohlleben': Der Lebensstandard der deutschen Zivilbevölkerung im Zweiten Weltkrieg. Vierteljahrshefte für Zeitgeschichte 58(3): 299-328.

CSO (Central Statistical Office). Fighting with Figures: A Statistical Digest of the Second World War. Edited by Peter Howlett. London: Central Statistical Office.

Collingham, Lizzie. 2011. The Taste of War: World War Two and the Battle for Food. London, Allen Lane.

Dallin, Alexander. 1957. German Rule in Russia, 1941-1945: A Study of Occupation Policies. London: Macmillan.

Davis, Lance E., and Stanley L. Engerman. 2006. Naval Blockades in Peace and War. An Economic History since 1750. Cambridge: Cambridge University Press.

Fremdling, Rainer, and Reiner Staeglin. 2014. Output, national income, and expenditure: an input–output table of Germany in 1936. European Review of Economic History 18(4), 371–397.

Gebhardt, Susan E., and Robin G. Thomas. 2002. Nutritive Value of Foods. U.S. Department of Agriculture, Agricultural Research Service, Home and Garden Bulletin 72.

Golson Eric. 2016. Neutrals at War. In Economic History of Warfare and State Formation, 259-278. Edited by Jari Eloranta, Eric Golson, Andrei Markevich, and Nikolaus Wolf. Singapore: Springer.

Hammond, R. J. 1951. Food, vol.1. The Growth of Policy. History of the Second World War: United Kingdom Civil Series. London: H.M.S.O.

Hancock, W. K., and M. M. Gowing. 1949. British War Economy. History of the Second World War: United Kingdom Civil Series. London: HMSO.

Harrison, Mark. 1990. A Volume Index of the Total Munitions Output of the United Kingdom, 1939-1944. Economic History Review 43:2, pp. 659-68.

Harrison, Mark. 1996. Accounting for War: Soviet Production, Employment, and the Defence Burden, 1940-1945. Cambridge: Cambridge University Press.

Harrison, Mark. 2024. Economic Warfare and the Battlefield on the Eastern Front, 1941-1945. Working paper (in progress).

Hornby, William. 1958. Factories and Plant. History of the Second World War: United Kingdom Civil Series. London: HMSO.

Karlbom, Rolf. 1965. Sweden's Iron Ore Exports to Germany 1933-1944. Scandinavian Economic History Review 13: 65-93.

Klein, Burton H. 1959. Germany's Economic Preparations for War. Cambridge, Mass.: Harvard University Press.

Klemann, Hein, and Sergei Kudryashov. 2012. Occupied Economies: An Economic History of Nazi-Occupied Europe, 1939-1945. London and New York: Berg.

Mackay, Robert. 2003. Half the Battle: Civilian Morale in Britain during the Second World War. Manchester: Manchester University Press.

Medlicott, W. N. 1952, 1959. The Economic Blockade, vols 1-2. History of the Second World War: United Kingdom Civil Series. London: HMSO.

Mierzejewski, Alfred C. 1988. The Collapse of the German War Economy, 1944–45. Chapel Hill: University of North Carolina Press.

O'Milward, Alan S. 1967. Could Sweden have stopped the Second World War? Scandinavian Economic History Review 15: 127-138.

Milward, Alan S. 1977. War, Economy, and Society, 1939-1945. London: Allen Lane.

O'Brien, Phillips P. 2015. How the War was Won: Air-Sea Power and Allied Victory in World War II, Cambridge: Cambridge University Press.

Olson, Mançur. 1962. The Economics of Target Selection for the Combined Bomber Offensive. Royal United Services Institution Journal 107(628): 308–14.

Olson, Mançur. 1963. The Economics of the Wartime Shortage: A History of British Food Supplies in the Napoleonic War and in World Wars I and II, Durham, NC: Duke University Press.

Overy, Richard. 1980. The Air War, 1939-1945. London: Europa.

Overy, Richard. 1994. War and Economy in the Third Reich. Oxford: Clarendon Press.

Overy, Richard. 2014. The Bombing War: Europe, 1939-1945. London: Penguin.

Salmon, Patrick. 1981. British Plans for Economic Warfare against Germany 1937-1939: The Problem of Swedish Iron Ore. Journal of Contemporary History 16(1): 53-72.

Scherner, Jonas. 2010. Nazi Germany's preparation for war: evidence from revised industrial investment series. European Review of Economic History 14(3): 433–468.

Scherner, Jonas. 2012. Der deutsche Importboom während des Zweiten Weltkriegs. Neue Ergebnisse zur Struktur der Ausbeutung des besetzten Europas auf der Grundlage einer Neuschätzung der deutschen Handelsbilanz. Historische Zeitschrift 294 (1): 79-113.

Scherner, Jonas. 2013. 'Armament in depth' or 'armament in breadth'? German investment pattern and rearmament during the Nazi period. Economic History Review 66(2): 395-691

Scherner, Jonas, and Jochen Streb. 2016. The Mirage of the German Economic Miracle in World War II. In Economic History of Warfare and State Formation, 243-258. Edited by Jari Eloranta, Eric Golson, Andrei Markevich, and Nikolaus Wolf. Singapore: Springer.

Süss, Winfried. 2003. Der "Volkskörper" im Krieg. München: R. Oldenbourg Verlag.

Todman, Daniel. 2016/20. Britain's War II. Vol. 1 (2016), Into Battle, 1937-1941. Vol. 2 (2020), A New World, 1942-1947. London, Allen Lane.

Titmuss, R. M. 1950. Problems of Social Policy. History of the Second World War: United Kingdom Civil Series. London, HMSO.

Toprani, Anand. 2019. Oil and the Great Powers: Britain and Germany, 1914-1945. Oxford: Oxford University Press.

USSBS (US Strategic Bombing Survey). 1945a. Summary Report (European War), Washington DC.

USSBS (US Strategic Bombing Survey). 1945b. The Effects of Strategic Bombing on the German War Economy. Overall Economic Effects Division. Washington DC.

Vickers, C. G. 1943. Economic Warfare. Royal United Services Institution Journal 88(549), pp. 14-22.

Vonyó, Tamás. 2012. The bombing of Germany: the economic geography of war-induced dislocation in West German industry. European Review of Economic History 16(1), pp. 97-118.

Webster, Charles, and Noble Frankland. 1961. The Strategic Air Offensive Against Germany, 1939-1945, vols 1-4. History of the Second World War: Military Series. London: HMSO.

## Tables

*Table 1. Bomb tonnage on the UK and on occupied Europe, 1940 to 1945*

| | German bomb tonnage on UK | Allied bomb tonnage on occupied Europe | Allied/German ratio |
|---|---|---|---|
| 1940 | 36,844 | 14,631 | 0.397 |
| 1941 | 21,858 | 35,509 | 1.62 |
| 1942 | 3,260 | 53,755 | 16.5 |
| 1943 | 2,298 | 226,531 | 98.6 |
| 1944 | 9,151 | 1,188,577 | 130 |
| 1945 | 761 | 477,051 | 627 |
| Total | 74,172 | 1,996,054 | 26.9 |

Notes: The German figure includes V-weapons (used from June 1944 to March 1945). For Allied bombing, the figures used here are those most nearly comparable to the German figures: the total tonnage dropped by the long-range bombers of RAF Bomber Command and the 8th and 15th US Army Air Forces, making 2.0 million tons of high explosives. A larger figure, 2.7 million tons, is the total of bombs dropped by all Allied air forces on all targets in the European theatre (USSBS 1945a: 1).

Source: Figures in tons are from Overy (1980: 120). Ratios are calculated from the figures given in the source.

*Table 2. Food availability in the UK, 1939-1945*

| | Prewar | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 |
|---|---|---|---|---|---|---|---|---|
| Imports under Ministry of Food (mn tons and quarterly rate) | … | *5.5 | **3.8 | 3.7 | 2.7 | 3.0 | 2.8 | |
| Home production, crops (mn tons): | | | | | | | | |
| --Wheat | 1.7 | 1.6 | 1.6 | 2.0 | 2.6 | 3.4 | 3.1 | 2.2 |
| --Potatoes | 4.9 | 5.2 | 6.4 | 8.0 | 9.4 | 9.8 | 9.1 | 9.8 |
| --Sugar beet | 2.7 | 3.5 | 3.2 | 3.2 | 3.9 | 3.8 | 3.3 | 3.9 |
| --Vegetables | 2.4 | 2.4 | 2.6 | 2.9 | 3.7 | 3.1 | 3.4 | 3.2 |
| Home livestock (mn head and mid-year) | | | | | | | | |
| --Cattle | | 8.9 | 9.1 | 8.9 | 9.1 | 9.3 | 9.5 | 9.6 |
| --Sheep and lambs | | 26.9 | 26.3 | 22.3 | 21.5 | 20.4 | 20.1 | 20.2 |
| --Pigs | | 4.4 | 4.1 | 2.6 | 2.1 | 1.8 | 1.9 | 2.2 |
| --Poultry | | 74.4 | 71.2 | 62.1 | 57.8 | 50.7 | 55.1 | 62.1 |
| Food stocks at end-of year (mn tons) | 10.5 | 7.5 | 10.6 | 13.4 | 13.7 | 15.8 | 15.0 | … |
| Energy consumed (thou. calories per person, average) | 3.0 | … | 2.8 | 2.8 | 2.9 | 2.8 | … | … |

Key: *October 1939 to June 1940. ** July to December 1940

Sources. Imports taken or calculated from Hancock and Gowing (1949: 206, 357). Home production from Hammond (1951: 393). Food stocks from Hancock and Gowing (1949: 207, 358). Energy consumed from Hammond (1951: 387), the figures given there being rounded to the nearest 100 calories in accordance with discussion in the accompanying text.

*Table 3. Real civilian outlays on consumer goods in Germany and the UK, 1938 to 1944 (per cent of 1938)*

| | United Kingdom | Germany | |
|---|---|---|---|
| | per cent of 1939 | Per cent of 1940 | Rebased to 1939 |
| 1939 | 100 | 108 | 100 |
| 1940 | 87 | 100 | 93 |
| 1941 | 81 | 97 | 90 |
| 1942 | 79 | 88 | 81 |
| 1943 | 76 | 87 | 81 |
| 1944 | 77 | 79 | 73 |

Source: Columns 1 and 2 from BBSU (1998: 76). Column 3 is calculated from the source.

*Table 4. Notifiable infectious diseases per 10,000 residents the United Kingdom,*

| | Dysentery | Diphtheria | Pulmonary tuberculosis | Scarlet fever | Typhoid fever |
|---|---|---|---|---|---|
| 1939 | 0.6 | 12.1 | 11.2 | 19.6 | 0.4 |
| 1940 | 1.0 | 13.1 | 11.4 | 15.9 | 0.8 |
| 1941 | 1.9 | 13.4 | 12.4 | 14.4 | 1.2 |
| 1942 | 2.0 | 10.8 | 12.9 | 20.8 | 0.2 |
| 1943 | 2.2 | 9.1 | 13.3 | 27.5 | 0.2 |
| 1944 | 3.6 | 6.4 | 13.3 | 22.1 | 0.2 |
| 1945 | 4.3 | 5.1 | 12.7 | 17.8 | 0.1 |

Sources. Calculated from total notifications in CSO (1995: 00), normalized by the mid-year resident population (1939) and civil population (1940 to 1945) from LCES (1970: 8).

*Table 5. Germany's gross national product and resources available, 1938-1943 (billions of Reichsmarks and 1939 prices) according to Burton H. Klein*

| | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 |
|---|---|---|---|---|---|---|
| Government expenditures | 33 | 45 | 62 | 77 | 93 | 109 |
| Consumer expenditures | 70 | 71 | 66 | 62 | 57 | 57 |
| Gross domestic investment | 13 | 14 | 10 | 7 | 6 | 5 |
| Net exports | 1 | –1 | –9 | –15 | –20 | –21 |
| GNP, total | 117 | 129 | 129 | 131 | 136 | 150 |
| Resources available, total | 116 | *130 | 138 | 146 | 156 | 171 |

Source: Klein (1959: 257). The total of resources available is either the sum of government and consumer expenditures and gross domestic investment, or GNP plus net imports (net exports with opposite sign). For 1944, Klein provides only a figure for real consumer expenditures – RM53 billion, 7 per cent less than in 1943.

Notes: * Corrected from 126 in the source.

**NEW6** The reader should treat all the figures in this table with circumspection. They provide only a rough guide to general trends and orders of magnitude. Real consumer expenditures may be overstated. Gross domestic fixed investment is certainly understated (although inventory investment may also be overstated), and some investment costs may be hidden in the figures for government expenditure. Finally, the contribution of the occupied territories to wartime resources available is certainly understated. In more detail:

(a) The level of household consumption may be overstated. A recent benchmark estimate of Germany's GNP for 1936, based on input-output data from the 1936 industrial census, yields RM53.2 billion of private consumption in 1936 (Fremdling and Staeglin 2014: 377), around 5 percent less than Klein's (1959: 252) 55.8 billion in the same year.

(b) The level of domestic investment may be understated. The Fremdling-Staeglin benchmark for Germany's GNP in 1936 shows RM11.4 billion of gross fixed capital formation, nearly twice the 6.2 billion found by Klein in the same year. (For inventory investment, however, the discrepancy, although smaller, runs the other way: RM3.0 billion according to Klein, 1.4 billion according to Fremdling and Staeglin.) Independently, Jonas Scherner (2010, 2013) has

identified various large and consequential omissions from the investment series available to Klein. Consistently, he finds industrial fixed investment of RM2.65 billion in 1936 (Scherner 2010: 438) compared with the previously accepted figure of 2.16 billion. Of greater significance is the discrepancy Scherner finds for the war years. Summing over the three years from 1941 to 1943, Klein (1959: 256) valued gross domestic investment at current prices at RM19 billion. But this sum is equalled or even exceeded by the RM19.1 billion that Scherner was able to find over the same period *for industrial fixed investment alone*.

(c) Net imports are underestimated, potentially by billions of Reichsmarks. Germany was able to exploit its occupied territories through many channels, not all of which were accounted for at the time. The figures omit, for example, foreign goods purchased and consumed by the German armed forces abroad without entering the country. They also omit the value of foreign goods seized and consumed without payment. Various estimates are available (Klemann and Kudryashov 2012: 75-117; Scherner 2012). But they have not been compiled for national accounting purposes. **End6**

*Table 6. German production, 1942-1945: Allied estimates of reduction attributed to Allied area bombing (per cent of estimated potential)*

| | USSBS estimates of loss of Reich production | BBSU estimates | |
|---|---|---|---|
| | | Loss of all industrial production | Loss of war industry production |
| 1942 | 2.5 | 0.7 | 0.5 |
| 1943 | 9.0 | .. | .. |
| First half | .. | 3.5 | 3.3 |
| Second half | .. | 10.5 | 6.9 |
| 1944 | 17.0 | .. | .. |
| First half | .. | 5.7 | 2.4 |
| Second half | .. | 9.0 | *2.6 |
| 1945 (Jan.-April) | 6.5 | *12.2 | *3.7 |

Sources: Webster and Frankland (1961, vol. 4: 482-483); see also BBSU (1998: 93,96).

USSBS (United States Strategic Bombing Survey): Over a sample of ten German cities, an index is constructed to show the intensity with which a city was bombed and the months of lost output associated directly and indirectly with the bombing. The loss of 2.71 percent of annual Reich production over the ten cities is averaged over the 39.9 thousand tons of bombs dropped on them. Extrapolation to area bombing of the Reich as a whole yields the figures shown.

BBSU (British Bombing Survey Unit): The “estimated percentage loss attributable to all town area attacks allowing for the lag in effects on industry . . . All percentages are in terms of the corresponding estimated potential production in the absence of town raids.” Figures for the first four months of 1945 are calculated “as though they took place over a six months’ period.” Figures marked with an asterisk (*) are “particularly conjectural, as they assume that war production could be maintained relative to all production as well as it was in January-June 1944.”

**New7**

*Table 7. Germany's war production shortfall and Allied bomb tonnage on economic targets in three periods, 1941-1945*

| | Germany's shortfall of war production, index units per quarter | | Allied bomb tonnage, thousands per quarter | |
|---|---|---|---|---|
| | | | Total | Of which, on transport |
| Period 1 | 0 | (complete adaptation) | 7 | 1 |
| 2 | -16 | (partial adaptation) | 81 | 27 |
| 3 | -123 | (collapse) | 285 | 113 |

Notes and sources: Germany's war production shortfall is actual war production less potential war production allowing for territorial losses, as shown in Figure 7. Index units are percentages of the level of production in January-February 1942. Period 1 runs from the start of 1941/Q2 (when the Allied bombing of economic targets began) to the end of 1943/Q1; period 2 from 1943/Q2 (when German war production first fell below potential but continued to rise) to 1944/Q2; period 3 from 1944/Q3 (when German war production peaked) to 1945/Q1. Allied bombing tonnages are as shown in Figure 3. **End7**

*Table 8. Energy content of food rations for a German worker family member, 1939/40-1945/46*

| | kCalories per day |
|---|---|
| 1939/40 | 2,435 |
| 1940/41 | 2,445 |
| 1941/42 | 1,928 |
| 1942/43 | 2,078 |
| 1943/44 | 1,981 |
| 1944/45 | 1,671 |
| 1945/46 | 1,412 |

Source: Abelshauser (1998: 155).

*Table 9. Feeding worker households in Germany in World War II: rationed energy and proteins from six food groups, by main breadwinner's type of work and age of children, per cent of average consumption in 1937*

| Type of work: | Heavy | | .. | Normal | |
|---|---|---|---|---|---|
| Age of children: | Older | Younger | | Older | Younger |
| Energy: | | | | | |
| End-1939 | 100 | 100 | | 91 | 91 |
| Mid-1942 | 93 | 92 | | 85 | 84 |
| End-1944 | 96 | 94 | | 87 | 85 |
| Proteins: | | | | | |
| End-1939 | 98 | 100 | | 86 | 88 |
| Mid-1942 | 83 | 82 | | 73 | 73 |
| End-1944 | 87 | 87 | | 76 | 77 |

Notes: The six food groups covered in this table are bread and flour, meat, fats, whole milk, eggs, and sugar and jam; fruit and vegetables (especially potatoes, rationed from April 1942) are not counted. The baseline is average consumption of a family of five (two adults and three children) with an annual income of 2,500 to 3,000 Reichsmarks in 1937. In wartime, rations were differentiated by class of employment (heavy labour attracted more energy and proteins) and age (older children were given more calories while younger children were given more proteins). In all cases the energy and protein content of rations is shown for a family of five. Older children in the table were 14, 10 to 13, and 3 to 6 years of age; younger children were 12, 7, and 1½ years.

Sources: Family rations are from Buchheim (2010: 317). Energy and proteins are converted on the basis of Gebhardt and Thomas (2002) as follows: bread and flour (#419 bread, whole wheat); meat (#764 fresh pork chop, lean and fat); fats (#154butter, unsalted), whole milk (#118); eggs (#140one medium size, raw); sugar and jam (#1024white granulated sugar). These conversions likely overstate the absolute quality of German wartime foodstuffs, but they suffice to provide relative weights for the index numbers reported in the table. No allowance is made for the deterioration of food quality from 1937 to the war years, described by Buchheim (2020: 319).

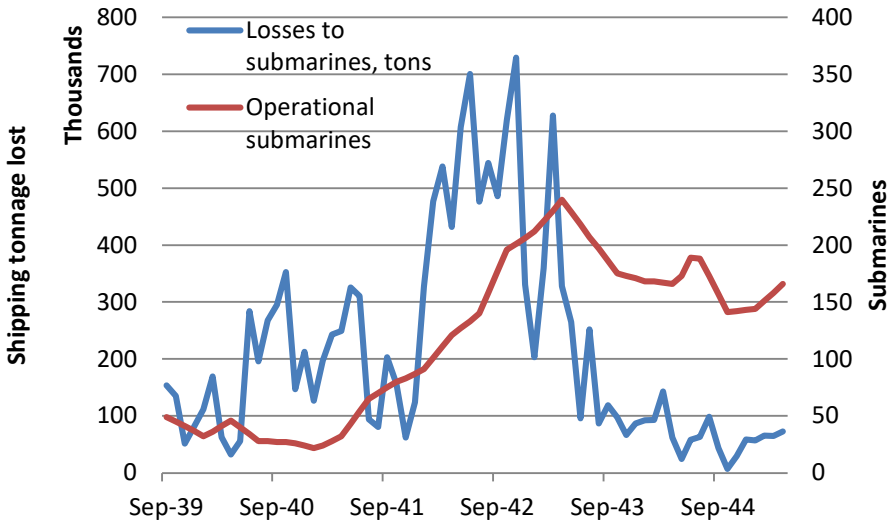
*Table 10. Notifiable infectious diseases per 10,000 residents in Germany in the two World Wars*

| | Dysentery | Diphtheria | Pulmonary TB | Scarlet fever | Typhoid fever | Typhus (spotted fever) |
|---|---|---|---|---|---|---|
| World War II | | | | | | |
| 1938 | 0.8 | 21.8 | 8.9 | 16.1 | 0.9 | 0.0 |
| 1939 | 0.9 | 20.6 | 10.5 | 18.5 | 0.8 | 0.0 |
| 1940 | 1.8 | 19.6 | 13.3 | 19.2 | 1 | <0.1 |
| 1941 | 1.2 | 24.1 | 13.4 | 34.3 | 1.9 | 0.1 |
| 1942 | 1.7 | 33.4 | 16.1 | 48.7 | 1.8 | 0.3 |
| 1943 | 0.8 | 33.5 | 17.4 | 48.4 | 1.9 | 0.4 |
| 1944 | 0.8 | 33.6 | 17.1 | 32.2 | 1.3 | 1.8 |
| World War I | | | | | | |
| 1914 | 0.9 | 19.2 | .. | 15.8 | 2.6 | 0 |
| 1915 | 1.2 | 26.1 | .. | 22.7 | 3.2 | 1 |
| 1916 | 1.5 | 29.9 | .. | 14.3 | 2.2 | <0.1 |
| 1917 | 10.5 | 26.7 | .. | 7.4 | 4.6 | <0.1 |
| 1918 | 4.8 | 24.8 | .. | 6 | 3.7 | <0.1 |

Source. Süss (2003: 442).

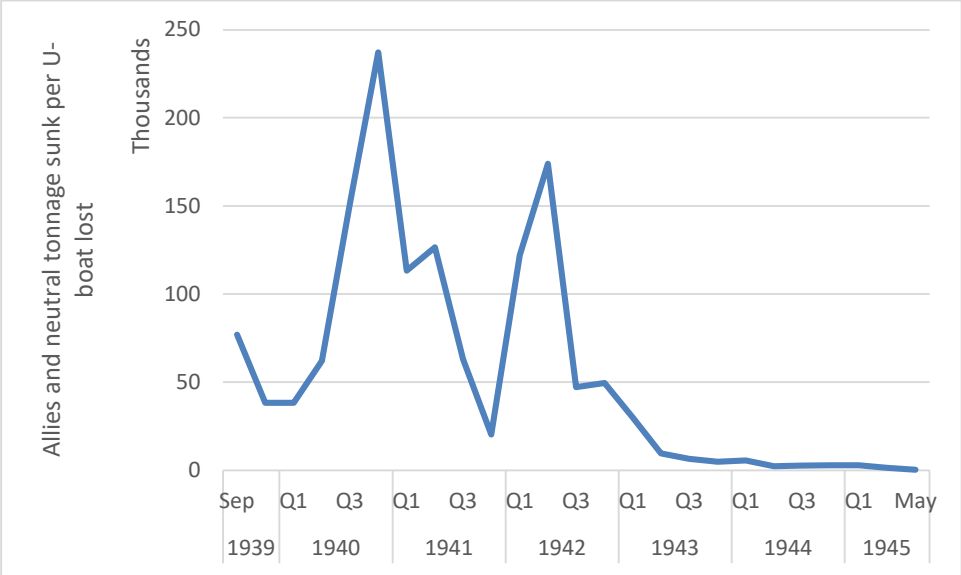
## Figures

*Figure 1. Germany's operational submarines and the sinking of Allied and neutral shipping, 1939-1944*



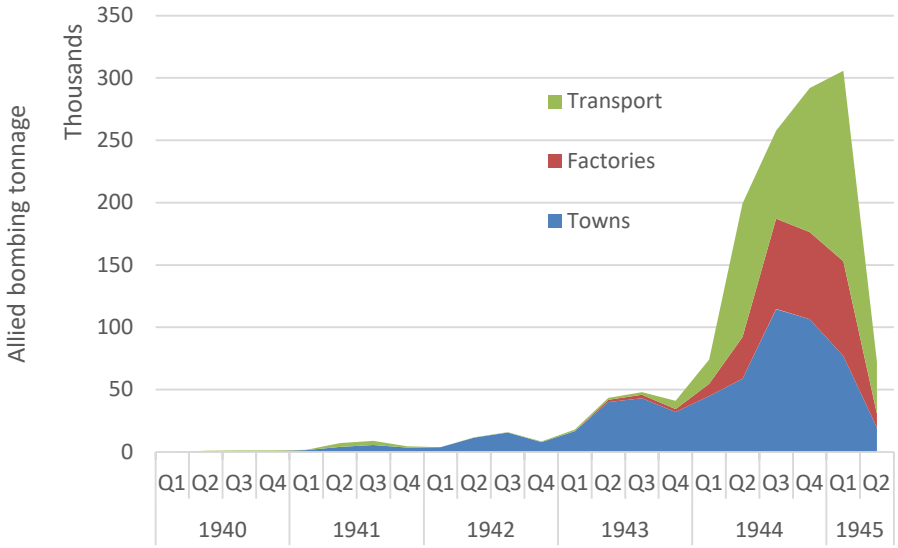

Source. Data from Davis and Engerman (2006: 298-300). Shipping losses are those attributed to submarine warfare (around three quarters of all losses).

*Figure 2. Allied and neutral shipping tonnage sunk per U-boat lost, September 1939 to May 1945*



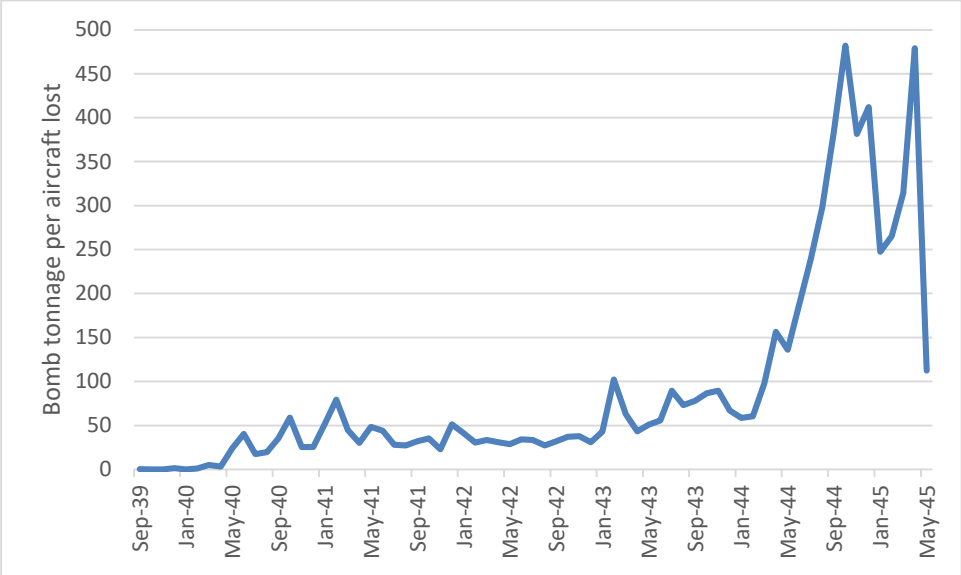

Source: As Figure 1. Monthly data are reported here on a quarterly basis because, in some months, no submarines were sunk.

*Figure 3. Allied bombing of economic targets, 1940 to 1945*



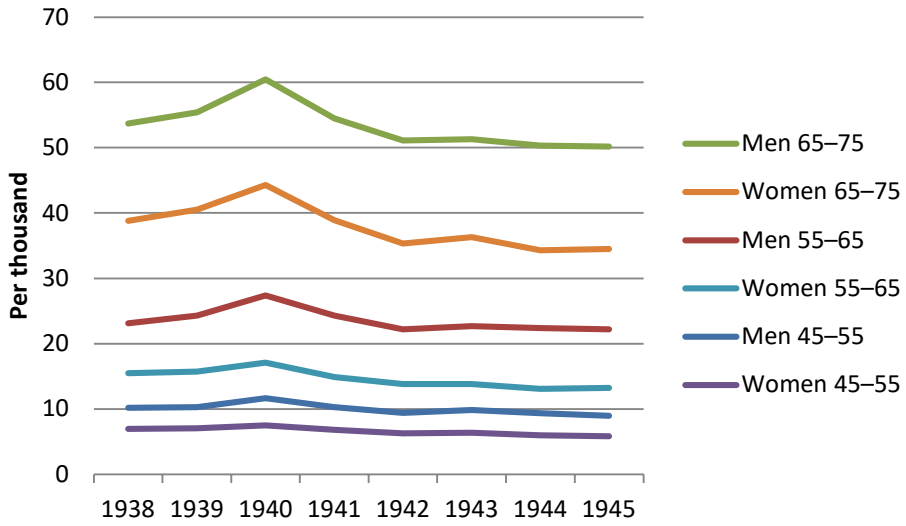

Source. Data from USSBS (1945b: 2-5). These figures cover approximately three-quarters (1.425 million) of the 2 million tons of Allied bombs dropped by RAF Bomber Command and the U.S. 8th and 15th Air Forces and listed in Table 1. Economic targets included towns (43 per cent), industrial facilities (20 per cent), and transport facilities (37 per cent). The remaining 575 thousand tons were dropped on "other targets," including submarine pens and airfields, in support of military operations.

*Figure 4. Bomb tonnage dropped by RAF Bomber Command per airplane lost, 1939 to 1945*



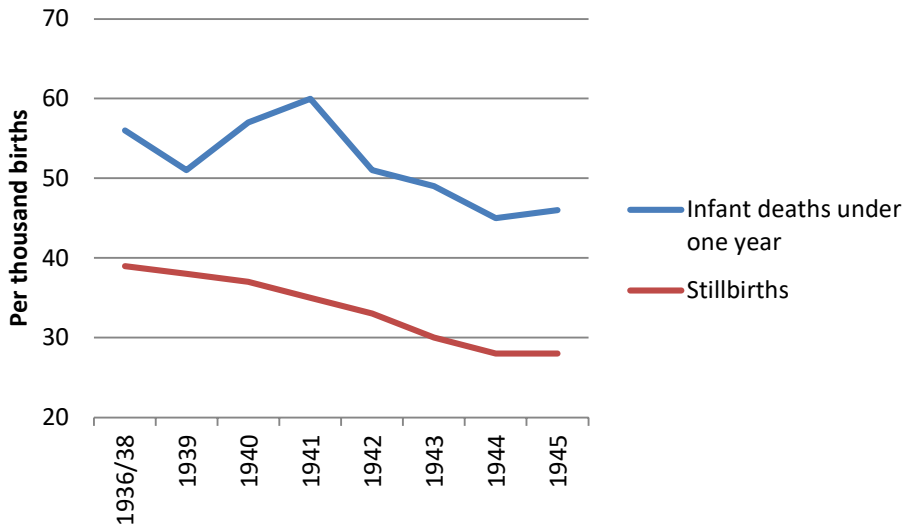

Source: Data from Webster and Frankland, vol. 4 (1961): 431-436, 455-457. Figures cover all Bomber Command operations, not just those directed against economic targets.

*Figure 5. Adult civilian male and female death rates at ages 45 to 75 years in the UK, 1938-1945*



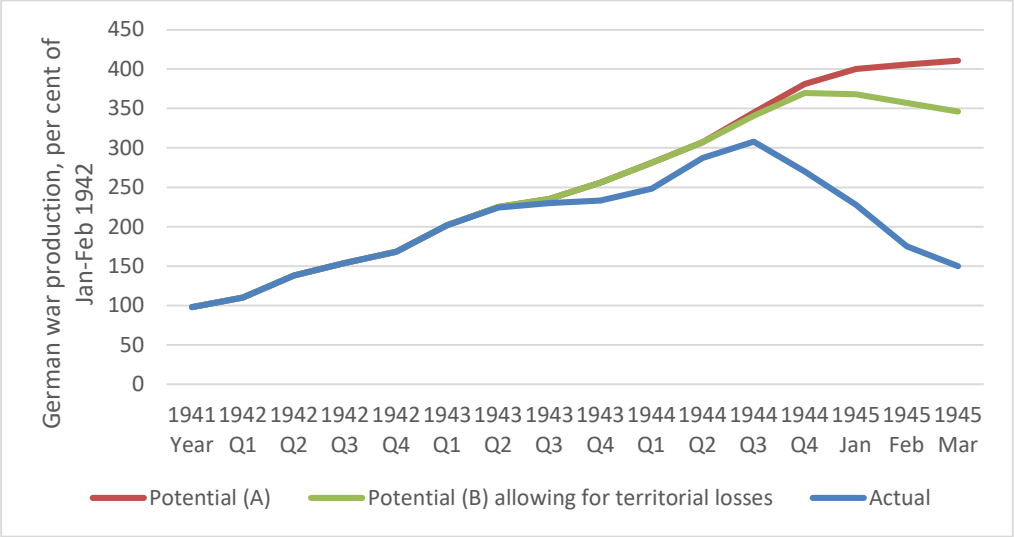

Source. Data from Titmuss (1950: 521). Causes of death exclude operations of war.

*Figure 6. Infant deaths and stillbirths in the UK*




Source. Data from Titmuss (1950: 524).

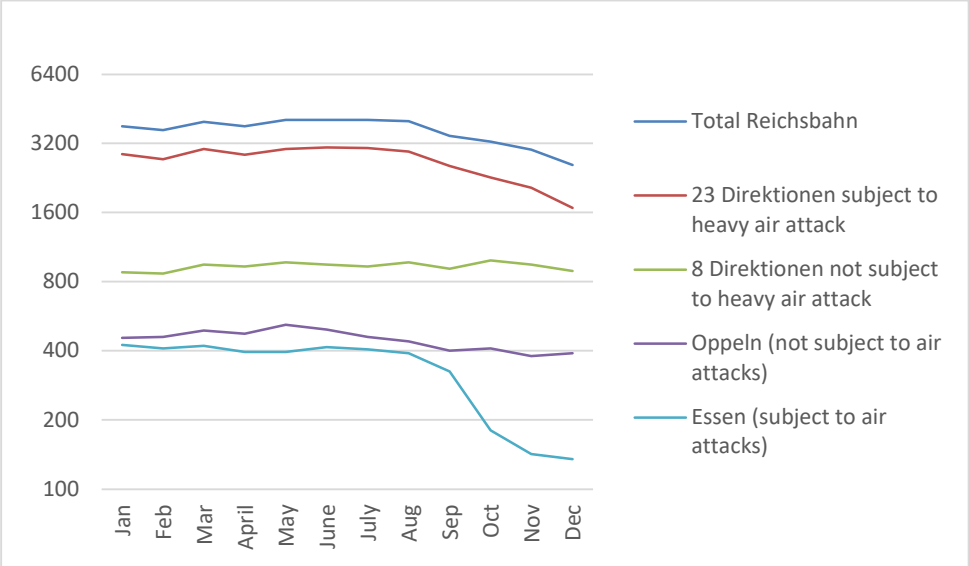
*Figure 7. German war production, potential and actual, 1941-1944 (percent of January-February 1942), according to Wagenführ and the BBSU*




Source: BBSU (1998: Figure 20, facing page 90). Actual production is the Wagenführ index; potential production is calculated by the BBSU.

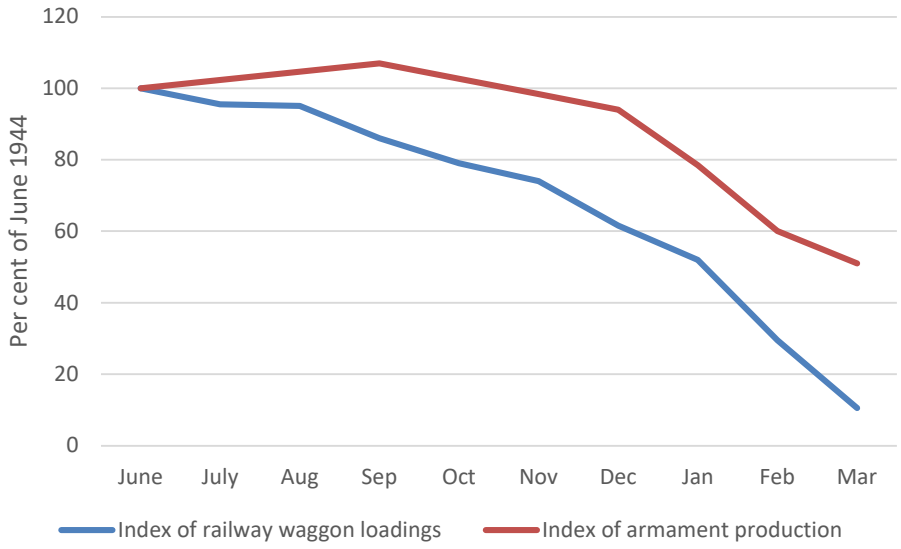
.

*Figure 8. Effects of Allied bombing on German railway waggon loadings across Reichsbahn Direktionen, January to December 1944*



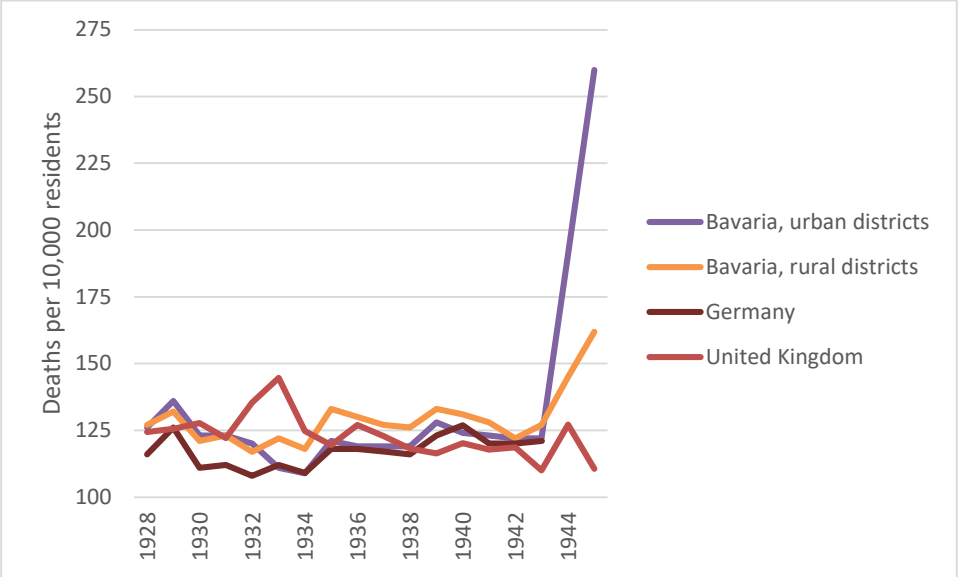

Source: BBSU (1998: Figure 47, facing page 129).

*Figure 9. War production and railway loadings, June 1944 to March 1945 (per cent of June 1944)*



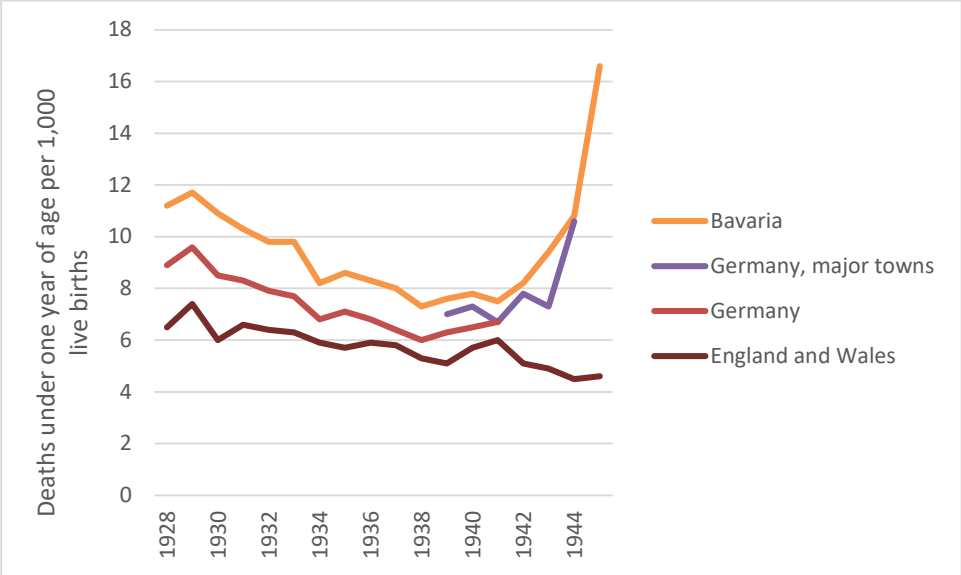

Source: BBSU (1998: Figure 42, facing page 134). Mierzejewski (1984: 198) gives a similar figure, comparing German monthly war production with monthly railway loadings in total and of hard coal, covering a longer period, January 1943 to March 1945.

*Figure 10. Mortality in Germany (including Bavaria by urban and rural districts), 1928-1945, compared to the United Kingdom*



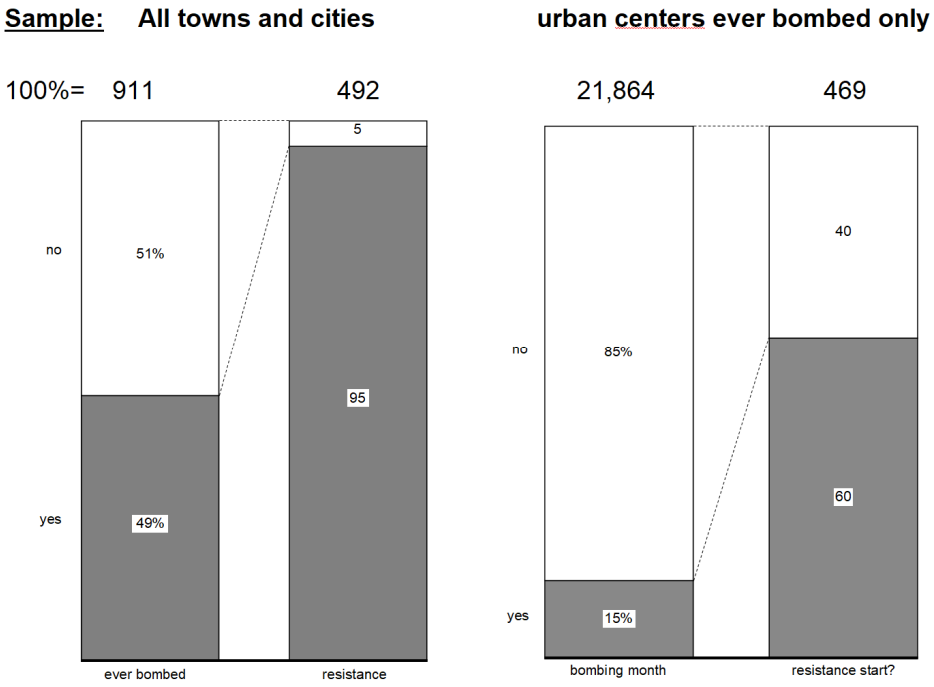

Source: Süss (2003: 447).

*Figure 11. Infant mortality in Germany (including Bavaria), 1928-1945, compared to England and Wales*




Source: Süss (2003: 447)

*Figure 12. Bombing frequency and risk of resistance, Germany, 1943-44*




Source: Adena et al. (2020) – author's communication.