

Total and Marginal Returns to Strategic Bombing: Germany, 1939-1945

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Abstract: Major war – the second world war, the second Indochina war, the Persian Gulf war, the Kosovo war – regularly renews the debate over the aims and results of strategic bombing. If bombing be compared to milking a cow, then tactical bombing upsets the pail of milk. In contrast, strategic bombing aims to kill the cow.

This paper makes a number of contributions: (a) it assesses the total and incremental effects of the strategic bombing of Germany; (b) it shows that *after* the “victory threshold” was crossed, the total effect of bombing is associated with a rapid decline of German war-making capabilities; (c) that the marginal effects of this post-threshold bombing exhibit highly unusual features; and (d) argues that the bombing of Germany was hardly “strategic” in a strict military sense. While this implies zero total and marginal returns, I suggest other ways to think about the marginal effects of bombing.

JEL codes: D74, H56 [also economic history; country study, Germany]

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Total and Marginal Returns to Strategic Bombing: Germany, 1939-1945

Introduction

Major war – the second world war, the second Indochina war, the Persian Gulf war, the Kosovo war – regularly renews the debate over the aims and results of strategic bombing.¹ If bombing be compared to milking a cow, then tactical bombing repeatedly upends the pail of milk as it is being refilled. Strategic bombing aims to kill the cow.

This paper makes a number of contributions: (a) it assesses the total and incremental effects of the strategic bombing of Germany; (b) it shows that *after* the “victory threshold” was crossed, the total effect of bombing is associated with a rapid decline of German war-making capabilities; (c) it shows that the marginal effects of this post-threshold bombing exhibit highly unusual features; and (d) it argues that the bombing of Germany was hardly “strategic” in a strict military sense. While this implies zero total and marginal returns, I suggest other ways to think about the marginal effects of bombing.

What is strategic bombing?

What is strategic bombing? In the memorable language of the United States Strategic Bombing Survey (USSBS),

... strategic bombing bears the same relationship to tactical bombing as does the cow to the pail of milk. To deny immediate aid and comfort to the enemy, tactical considerations dictate upsetting the bucket. To ensure eventual starvation, the strategic move is to kill the cow (USSBS, 1947, p. 5).

Less originally, consider the following two definitions:

Strategic bombing ... is aimed at the systematic destruction of those resources which will most weaken the enemy by denying him the materials or weapons he needs to prosecute the war (USSBS, Jan. 1947, p. 2, pt. 2).

Strategic bombing is best defined as the use of air power to strike at the very foundation of an enemy’s war effort – the production of war material, the economy as a whole, or the morale of the civilian population – rather than as a direct attack on the enemy’s army or navy. A strategic air campaign almost always requires the defeat of the enemy’s air force, but not as an end in itself. While tactical air power uses aircraft to aid the advance of forces on the ground or on the surface of the ocean, usually in cooperation with those forces, strategic air power usually works in relative independence of armies and navies ... (Levine, 1992, p. 1).

In the hope that military efforts will be starved, strategic bombing, the first definition suggests, is about bombing of non-military assets. One shoots at the economic cow that (re)fills the military’s pail. The focus on the ultimate objective – the opponent’s ability to prosecute the war – is operationally vague and is at any rate restricted to the physical inputs to war-making, neglecting human capital and institutional aspects. The definition also lacks operational clarity. The second definition helps to separate out strategic from tactical bombing and identifies three operational objectives: (a) the opponent’s actual arms production; (b) the enemy’s potential to produce civilian and military goods; and (c) the morale of the adversary’s civilian population. The definition also suggests that strategic bombing is to achieve certain war outcomes by itself, to avert the need for a land-based invasion of the opponent’s territory, the capture of its capital, and the deposing of its leaders.

As we shall see, the strategic bombing of Germany during the second world war was not pure, and many claim that strategic bombing was never meant to achieve victory all by itself (e.g., Levine, 1992, p. 192). But this line of argument is suspect: if strategic bombing is not meant to achieve victory – by attacking the enemy’s war production, its economy, and the morale of its people – then what is it to achieve and exactly what is its contribution to the overall war effort? For the case of Germany the evidence suggests that the contribution of strategic bombing was slight; indeed its primary contribution was made in support of tactical operations, namely preparing for D-Day and for the invasion of Germany.

Data and findings

Bombing data are available from December 1939 (12/39) to May 1945 (5/45). The data is classified by tonnage dropped, by country/region on which the bombs were dropped (Germany, France, Italy and Sicily, Austria, Hungary, and the Balkans, and “all other countries”), by who dropped the bombs (the RAF or the USAAF), and by target class. The ten target classes were: (1) aircraft factories; (2) airfields/aerodromes; (3) oil, rubber, chemicals, and explosives (OCRE); (4) land transportation (mainly rolling stock, railroad yards, and bridges); (5) V-weapon launching sites; (6) naval and water transportation (e.g., canals, river bridges); (7) miscellaneous manufacturing (armaments, tanks, motor vehicles, machinery and equipment, bearings, electrical products, optical and precision instruments, steel, light metals, radio and radar, and “manufacturing not identified”); (8) industrial areas (i.e., towns and cities); (9) military targets; and (10) and all other targets.² The data used in this paper are taken from the statistical appendix to the overall report on the European war produced by the United States Strategic Bombing Survey (USSBS, February 1947).³

This paper provides empirical evidence that the total effect of bombing on German weapons production was minimal until the third quarter of 1944 (III/44), that the total effect on the German civilian economy likewise was minimal, and that the impact of bombing on German morale was relatively small. After III/44, strategic bombing, strictly defined, did not take place since Eisenhower had assumed command over all allied strategic air forces for tactical operations in support of the invasion of Germany. By definition, therefore, “strategic” bombing after III/44 shows zero total and marginal effects, even though the effect of the tactical bombing was devastating. If one regards this as a “slight-of-hand” argument and nonetheless wishes to examine the marginal effect of bombing – strategic or otherwise – it turns out that, with the exception of morale bombing, it is very difficult to establish these effects for reasons that will become clear shortly.

A production function for strategic bombing: the problem of inputs

Macabre though it may be, in principle the effect of bombing is amenable to economic analysis. One need merely relate a set of inputs to some defined output. For example, one may write

$$(1) \quad y_i = f(\mathbf{x}_A; \mathbf{x}_D; \mathbf{z})$$

where y_i denotes the destruction of the defender’s assets (i.e., destruction of enemy assets is viewed as a positive outcome), \mathbf{x}_A is a vector describing the attacker’s input variables, with expected positive

coefficients, \mathbf{x}_D is a vector describing the defender's input variables, with expected negative coefficients, and \mathbf{z} is a vector that captures imponderables, such as prevailing weather conditions.⁴

The list of inputs is potentially huge. Obvious inputs include the number of sorties flown, the number of bomber aircraft available, the fuel range of the bombers, the bomb load each bomber could carry, the type of bomb carried, and the explosive or incendiary charge of each bomb. Less obvious are the accuracy of the navigation system, the accuracy of the bomb-sighting equipment, the availability and range of escort fighters, and the flight training and experience of pilots, navigators, bombardiers, and gunners. As mentioned, improvement in these inputs would be expected to result in a positive coefficient if the production function were econometrically estimated. Improvements in German air defenses – such as search lights, flak, interceptor aircraft, air defense strategies – would be expected to yield negative coefficients.

Although these data are in fact available in astonishing detail, I have not endeavored to actually put a data set together beyond the descriptive data set of monthly tonnage by country, bombing force, and target class. The reason is that the input variables changed so rapidly during the war that practically every mission consists of a unique set of input values, making it econometric impossible to estimate reliable and meaningful coefficients. For example, of the 66 months in the data set (12/39 to 5/45), there are 23 months during which the United States Army Air Force (USAAF) bombed aircraft factories in Germany. But, statistically, the available degrees of freedom rapidly approaches zero when one now controls for a very large number of potential shift factors. These include, remember, German defensive efforts as well as evasive and substitution efforts. For example, the Germans were later discovered to have dispersed aircraft production around the country so that even if particular assembly sites were hit, the effect on aircraft production was minimal.

The output of strategic bombing

A further problem is that it is not clear exactly how to define, for purposes of econometric estimation, the output of strategic bombing. Clearly, the allies thought that bombing of towns and cities might reduce the morale of German workers, induce absenteeism and thereby sufficiently disrupt civilian and war-production to coerce surrender. As we will see momentarily, this did not happen. Moreover, Nazi Germany made ample use of foreign and slave labor who could not be more demoralized than they already must have been. Although some have disputed the point (e.g., Overy, 1994; Cox, 1998; Abelshausen, 1998), research suggested – at least to the allies – that German civilian production was not much affected by strategic bombing (USSBS, October 31, 1945).⁵ But even if it did, it is not clear how this would necessarily have undermined Germany's war-making capability. And if, finally, the output of bombing was thought to consist of the reduction of Germany's weapons production then the allies were rightly shocked to discover that German arms production rose more than threefold between early 1942 and III/44 and, even at the end of the war, contained ample inventories of weaponry. Both in the civilian and in the military sphere, Nazi Germany found many alternative ways of securing supplies and getting things done (see any of the sources in the list of references; there is no disagreement among sources on the point).

Ultimately, Germany faltered because it could not match weapons to soldiers; it failed because its economic infrastructure collapsed as the strategic forces – commandeered by Eisenhower – targeted fuel supplies and land transportation systems in conjunction with the crossing of the Rhine

and the march on Berlin (Levine, 1992; Pape, 1996; BBSU, 1998; USSBS, September 30, 1945). What was it that allowed Eisenhower to cross the channel, invade Normandy, cross the Rhine river, invade Germany, and engage in devastating bombing? What happened around 6 June 1944 that had not happened before? The answer, the narrative record of military history suggests, is that the allied forces won the air war against the German Air Force in early 1944. (Again, all sources appear to agree on this point; I have not found any dissenting voice.) But winning the air war in aerial combat is tactical, not strategic, warfare. Thus, lacking success in the air war, strategic bombing was unsuccessful; but with success in the air war, bombing was not *strategic* bombing in the strict sense of the definition anymore since the war at that point had been won. The best one can say is that after D-Day strategic bombing was an empty formalism: it conformed to the targets (war-related production, civilian economy, morale bombing) but not to the original goal. This kind of bombing probably shortened the war, but did not win it independent of land forces. Strategic bombing is not a substitute for, but a complement of, land forces – an important point illustrated in the Persian Gulf war of 1991 but not remembered in the Kosovo war of 1999.

Bomb tonnage, distribution, and targets

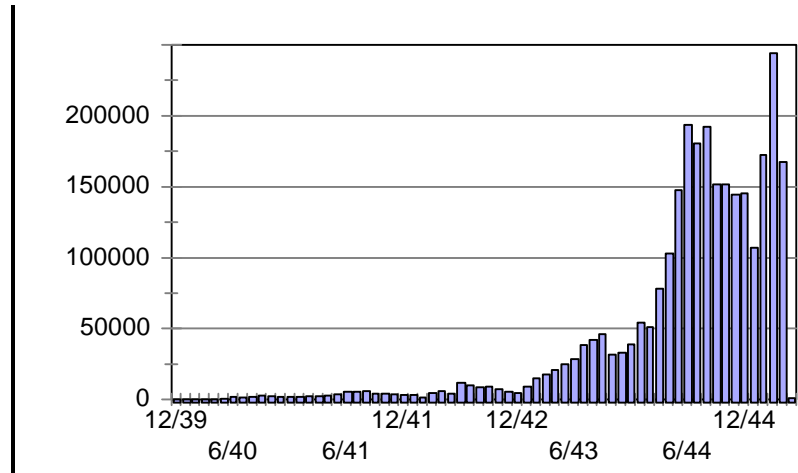


Figure 1: Bomb tonnage by month, European war, 12/39 to 5/45

The total tonnage dropped on the European landscape was nearly 2.8 million tons (see figure 1). US forces joined the Royal Air Force (RAF) in late 1942, seeing increasing action during 1943. But the lack of escort fighters led to huge allied loses, culminating in a particularly disastrous USAAF bombing mission on ball-bearing factories in Schweinfurt on 14 October 1943. At the end of the day 62 aircraft had been lost, and a further 138 damaged, for a

total of 200 aircraft out of the 228 that flew that day (Daniels, 1981, p. xviii). The notion of daytime *precision bombing* missions deep into the German heartland was abandoned – a notion the British had given up much earlier – and *area bombing* became the default option until new technologies, such as long-range fighters escorting the bomber fleets, could be developed. For the time being, the notion of *strategic bombing* had been given up.⁶ The USSBS, and others, would later argue that a theoretically pure form of strategic bombing either had not been intended all along, or had simply been impractical in light of other war contingencies.⁷

In early 1944, bombing increased massively in preparation for D-Day, dropped off in the second half of 1944, and saw its gruesome peak in April 1945. The nearly 250,000 tons dropped in that month alone are almost equal to the total tonnage dropped in the three-and-a-half years from 12/39 to 6/43. As regards Germany, table 1 shows that by the end of January 1944, only 20 percent of the

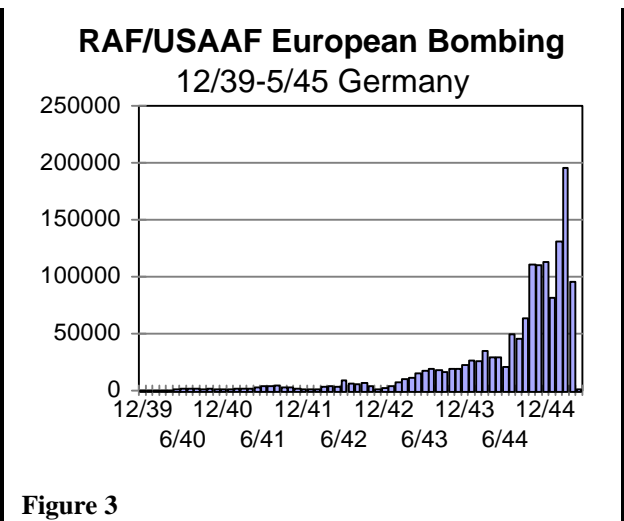
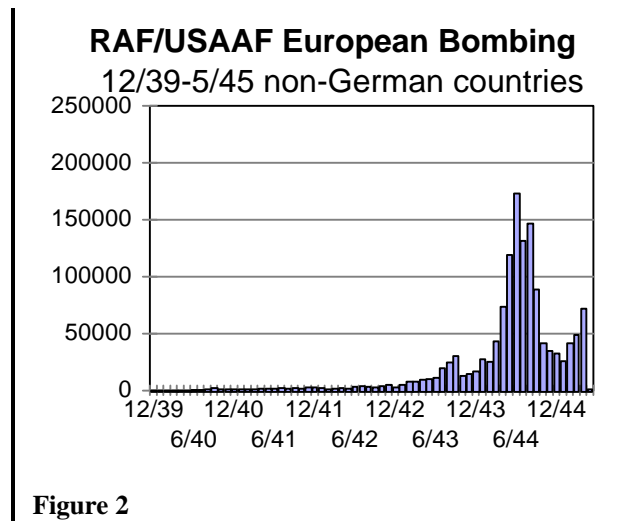


Figure 2

Figure 3

Table 1: Percentage of entire bomb tonnage dropped on Germany by allied forces by end of given month/year

Mth/Yr	Percentage
6/43	10.42
1/44	20.42
6/44	30.39
9/44	41.63
10/44	49.46
11/44	57.24
12/44	65.25
1/45	70.98
2/45	79.95
3/45	93.52
4/45	99.98
5/45	100.00

Source: calculated from USSBS (February 1947), chart 6, pp. 49-91

tonnage to be dropped on Germany had been expended. Even after D-Day, 70 percent of the total tonnage had yet to be dropped on Germany. If strategic bombing was meant to be decisive for the war effort, 30 percent of the total tonnage eventually dropped seems to have sufficed.

Of the total tonnage of about 2.8 million tons, slightly less than half was dropped on Germany, the remainder on the territories it occupied at one time or another (see figures 2 and 3). The figures reveal the concentrated allied bombing effort in preparation for the invasion of Normandy and the subsequent shift in the bombing effort, after June 1944, toward targets located in Germany. Detailed figures are available on the author’s web site, showing monthly tonnage by country (non-Germany and Germany) by target class.⁸ Drawn to the same tonnage and time scales, these show for non-German targets prominent spikes on land transportation and military targets around June 1944 with run-ups to smaller spikes on airfields, ORCE, and towns, also around June 1944. For targets in Germany, the pattern shifts to post-June 1944 bombing. ORCE targets receive nearly constant bombing of around 12,000 tons per month. Land transportation targets are heavily bombed, on an increasing trend line, as from September 1944. But the most noticeable target is the euphemistically called “industrial areas,” i.e., towns and cities which received an average of 52,000 tons of bombing per month between July 1944 and April 1945. The prevalence of city-bombing (also shown in table 2) stemmed particularly from RAF frustration with ineffective strategic bombing so that area bombing became at default option, and increasingly, an obsession by its commander, the aptly named “Bomber

Harris.” In later phases of the war, the Americans had great difficulty getting Harris’ cooperation to bomb non-civilian targets.

Table 2: Percentage of total bombing tonnage per month dropped on “land transportation” and “industrial areas” targets, June 1944 - May 1945

<i>Mth/Yr</i>	<i>Land transportation</i>	<i>Industrial areas</i>
6/44	9.43	14.26
7/44	7.47	45.02
8/44	4.78	29.25
9/44	28.15	26.44
10/44	23.07	46.58
11/44	21.67	36.51
12/44	54.96	19.24
1/45	54.55	21.57
2/45	44.20	28.93
3/45	32.22	25.42
4/45	34.65	19.33
5/45	6.10	81.36

Source: calculated from USSBS (February 1947), chart 6, pp. 49-91

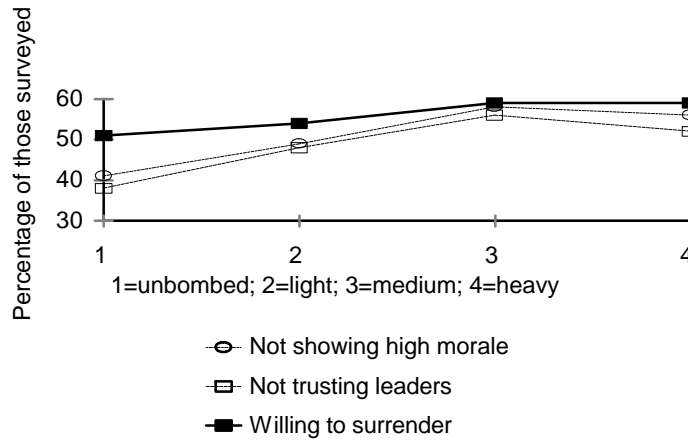


Figure 4: Diminishing returns of allied strategic bombing on German people's morale
Source: constructed from USSBS (Sept. 1945), p. 96

The effect on German morale

The United States Strategic Bombing Survey (USSBS) concluded that while the total effect of strategic bombing “appreciably affected the German will to resist” (USSBS, Sept. 1945, p. 95), it “soon led to diminishing returns in morale effects ... [so that the morale of those living in] ... towns subjected to the heaviest bombing was no worse than in towns of the same size receiving much lighter bomb loads” (USSBS, 1945, p. 96). Figure 4, constructed from data in USSBS, shows this diminishing effect. The percentages on the vertical axis are stated in terms of the allies’ desired outcome: the percentage of people *not* showing high morale, of people *not* trusting leaders, and of people willing to surrender. All three variables show diminishing returns as a function of increasing amounts of bombing. Note that even in the absence of bombing, forty to fifty percent of the German population was demoralized. Bombing brought that percentage more surely to the fifty percent mark but not much beyond that (this point is also made by Pape, 1996, p. 272, fn 48). And the British wrote: “In so far as the offensive against German towns was designed to break the morale of the German civilian population, it clearly failed.” (BBSU, 1998, p. 79).

The effect on German war production and its civilian economy

The allies underestimated the resilience of the attacked country. Indeed, the allies failed to realize that Germany had not fully mobilized at all when the war started in 1939 and therefore had plenty of spare industrial capacity to gear up war production as from 1942. This corresponds to the allies’ own assessment, as given in their respective bombing surveys. For example, the British write

... the most careful study has failed to provide any evidence to support the major economic inferences derived during the war from the physical picture of destruction. Paradoxically, ... war production, far from falling as a

result of the levelling of the German cities, continued to mount until the second half of 1944, and its subsequent fall had little to do with the continued bombing of centres of population. It was in the military, not the economic spheres that our attacks had their major strategic effects ... (BBSU, 1998, p. 69).

And the Americans write:

... For [the early war] years the conclusion is inescapable that Germany's war production was not limited by its war potential – by the resources at its disposal – but by demand; in other words, by the notions of the German war leaders of what was required to win (USSBS, Sept. 30, 1945, p. 31).

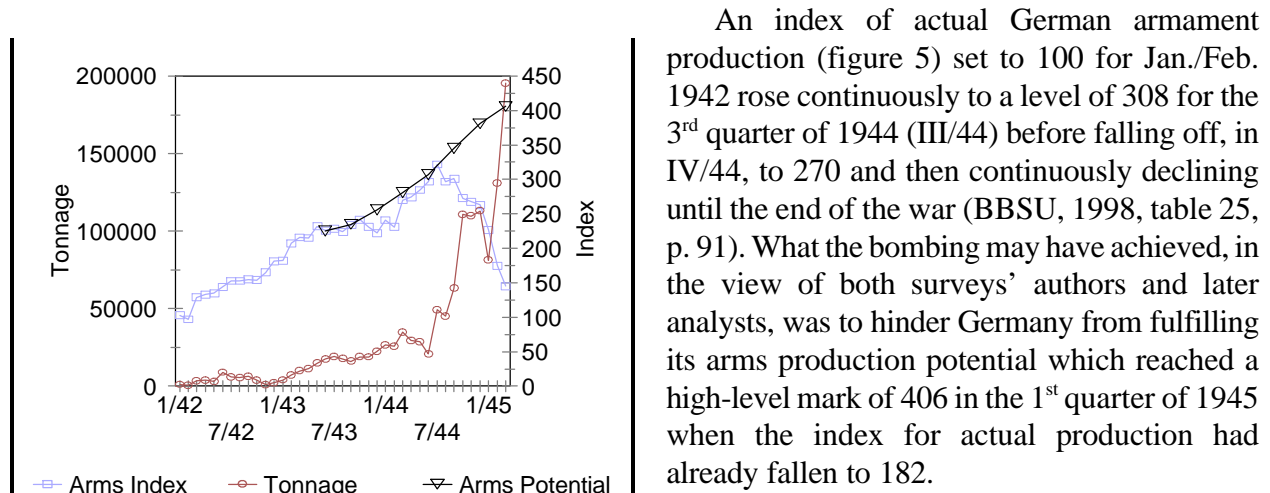


Figure 5: Monthly index of actual and potential German arms production, and tonnage of bombs dropped by combined strategic forces, 1942-1945
 Sources: USSBS, February 1947, p. 13 (tonnage), p. 113 (arms index), and BBSU, 1998, p. 91 (arms potential)

An index of actual German armament production (figure 5) set to 100 for Jan./Feb. 1942 rose continuously to a level of 308 for the 3rd quarter of 1944 (III/44) before falling off, in IV/44, to 270 and then continuously declining until the end of the war (BBSU, 1998, table 25, p. 91). What the bombing may have achieved, in the view of both surveys' authors and later analysts, was to hinder Germany from fulfilling its arms production potential which reached a high-level mark of 406 in the 1st quarter of 1945 when the index for actual production had already fallen to 182.

If this assessment is correct, two questions arise: (a) why had Germany not fully mobilized,⁹ and (b) where did it find the spare capacity to boost arms production “when our current information was that her production facilities were already strained to the upmost” (BBSU,

1998, p. 79)? The undisputed, answer to the first question is that the German military had long planned for successful series of short wars (the “Blitzkrieg” doctrine) and that the civilian and war-making sectors of the economy were balanced accordingly. Only when the war took longer than Germany had planned, did the need for increased armament production arise (e.g., in BBSU, 1998, pp. 70, 84, 86, 101, and virtually every other source we consulted).

The answer to the second question – where did the spare capacity to produce arms emerge from? – begins with an apparent paradox. Far from diminishing returns to increases in tonnage of bombing there appeared to result negative returns! That is, the higher the level of bombing, the higher Germany's arms production index rose, at least until June 1944 (figure 5). One explanation is that strategic bombing aimed at the wrong targets, another that the number of groups of targets was too diffuse (oil and fuels, docks and ports, rail and rolling stock, aircraft factories and airfields, general industry and cities, etc.), thinning the relatively small number of bombers over too many target groups. Further, not that the number of targeted groups was large but that a strategically important group, say fuel, had been correctly targeted but itself was widely dispersed throughout Germany and thereby more difficult to attack. Moreover, that bombing accuracy was low, that bad weather

prevailed, that long-range bombers were only slowly becoming available (but not always with fighter escorts), that bomb loads were small, that the bombs themselves were too small to produce much damage, and that the strategic forces were diverted to other theaters of war (e.g., North Africa) or to tactical missions (e.g., D-Day). And that Germany increased arms production, quite unrelated to the strategic bombing effort, simply as a demand-driven response to other aspects of the war. Virtually all sources adduce these and other reasons at one point or another.

Note in figure 4 that German arms production increased rapidly until just after D-Day when the land invasion of Germany began, and that its potential to produce arms grew right to the end of the war. The area bombing of industrial towns and cities in particular was thought not only to diminish production capacity but to demoralize the population, killing many, and making homeless many more. But production rose, and morale was not significantly affected as we have seen earlier. In a striking passage the BBSU report states:

However totalitarian may have been the political and military aspects of German life, the fact is that the German war economy and the organisation of production in Germany, were less totalitarian than either their British or American counterparts. Indeed, the failure of the Germans to exploit their potential industrial resources is to many the most surprising fact that has come to light since the end of the European war. Almost to the end ... German war production still possessed great reserves of capacity" (BBSU, 1998, p. 67).¹⁰

Whence, then, this productive capacity and why was it not used? Even though war mobilization reached 13 million people, the total German civilian labor force fell by only 3.5 million, from 39.4 to 35.9 million. Correspondingly, the greatest decline occurred in the male civilian labor force which fell from 24.5 to 13.5 million. This decline of 9 million was nearly made up by 7.5 million foreigners and prisoners of war. The average work week changed hardly at all (from 47.8 to 48.3 hours/week between September 1939 and March 1944). Women's labor force participation changed negligibly from 14.6 to 14.9 million. As regards capital, Germany had a comparatively high capital/labor ratio and the vast majority of industrial work was carried out in single shifts. Even of the crucial arms production facilities, only one fifth to one quarter worked a second shift. Strategic bombing damaged or destroyed a mere 6.5 percent of installed German machine tools. This was easily replaced. Given Germany's "Blitzkrieg" planning, raw materials were also ample – at least for about six months or so after the start of the war. Thereafter, in addition to materials recycling and product redesign, successful campaigns replenished supplies such as "chromium from Bulgaria and Greece, nickel and molybdenum from Finland and Norway, copper from Yugoslavia, Norway and Finland, manganese from Russia, mercury from Italy and Spain, and bauxite from Hungary, France, Yugoslavia and Italy" (USSBS, Oct. 31, 1945, p. 10).¹¹ It was not until mid to late 1944 that raw material shortages began to affect civilian and armament production.

In addition, Germany had large inventories of required materials, so that temporary setbacks in raw material production did not noticeably affect production of finished civilian and war goods. Moreover, German industry was geographically widely dispersed and further dispersed its critical industries that were too concentrated in too few locations. At best, the strategic air war appeared to secure modest delays in further increases in German production, rather than securing decreases. A well-thought through set of calculations shows that Germany's overall war production potential diminished, on account of strategic bombing, by a mere 2 percent or so, with the high point of a 3.8 percent reduction occurring in the second half of 1943, well before D-Day (BBSU, 1998, table 27,

p. 96).

Why did Germany not make use of its increasing arms production potential? And why did its actual arms production fall as from III/44? The answer is that the allied forces used II/44 to achieve air superiority over France to prepare for D-Day, 6 June 1944 (the invasion of the German-held Normandy beaches in France). It is in II/44 that allied bombing of Germany falls drastically from 35,000 to 21,000 tons and that Germany sees the largest increase in its index of actual arms production (figure 4). In July 1944, the index reached its apex at 322, arms production at a rate of more than thrice that of Jan./Feb. 1942. In August and September the index falls to 297 and 301, respectively, about even each month, and then declines precipitously. Once the dam was breached in the land war, German arms production held out for only one more month (July), struggled for August and September, and then collapsed.

Only at this point, when Germany's military had been broken, when its forces had been driven back to its own western borders by late August 1944, when it had lost the production facilities it had set up, and the raw material supplies it had secured, in the occupied territories, did bombing increase dramatically (see table 1 and figure 3). During preparations for D-Day, tonnage dropped on Germany declined by one-third from 35,000 tons in March 1944 to 21,000 tons in June 1944, and then jumped by more than twice to 49,000 tons in July and to more than twice that amount again by December 1944, finally increasing to nearly 200,000 tons in March 1945.

Why did Germany lose the war?

These data raise at least two questions: (a) what accounts for the decisive military break-through if not the preponderance of strategic bombing, and (b) if the purpose of strategic bombing is to achieve military objectives then what was the purpose of the remaining 60 percent (after II/44) or 70 percent (after III/44) of bomb tonnage still to be dropped on the country? Addressing (b) first, "strategic" bombing metamorphosed into tactical and punitive bombing in the last nine months of the war. This judgment is, at first sight, softened by the data in table 2. There I record, by month, the percentage of tons of bombs dropped on Germany and directed against "land transportation" targets and against "industrial areas" (i.e., towns and cities) targets. In June 1944, of the total tonnage directed against all targets in Germany, less than 10 percent was directed against land transportation and less than 15 percent against cities, i.e., altogether less than 25 percent of the total tonnage that month. In July, nearly half of the total tonnage was directed against cities. In August and September, about 25 percent each month.

The pattern of table 2 is that from September 1944 to April 1945 from 20 to 50 percent of the total monthly tonnage was directed against land transportation (primarily the railroad system). This was done to undermine German war production but, more often, had the effect of disabling Germany's capacity to deliver weapons to troops. However, "[t]he important point is that operations were interdicted mainly by tactical air attacks and these effects would have occurred even if the strategic offensive had not taken place" (Pape, 1996, p. 279). It was, in other words, *not* strategic but tactical support bombing. Indeed, the allies' strategic bombing forces were under Eisenhower's tactical command since April 1944 (Levine, 1992, p. 161). "Supporting Eisenhower's forces [was] the paramount consideration" (Levine, 1992, p. 165). This does not mean that Eisenhower made use of 100 percent of the allies' strategic bombing force, but he made use of what he wanted to use. For example, during January 1945, three-fourths of the strategic air force efforts "went to tactical

missions in support of the land armies” (Levine, 1992, p. 176).

Tonnage dropped on cities also ranged from 20 to 50 percent of the total, and, as we already noted, did not reduce arms production, nor reduce morale. Strategic bombing had become tactical and punitive bombing. The objective was not military anymore, but political. Since Germany failed to surrender, the objective of strategic bombing changed “from coercion to conquest” (Pape, 1996, p. 279).

Turning to point (a) – what accounts for the military break-through in June of 1944? – nearly all analysts, including BBSU and USSBS, answer that the allied forces finally achieved air superiority in air-to-air *fighter* combat as from early 1944 (e.g., Pape, 1996, p. 274; Levine, 1992, ch. 7). This resulted from three sources: first, Germany increased its production of *fighter* aircraft too late (e.g., USSBS, Sept. 1945, p. 14); second, in spite of eventually producing large number of additional fighters – astonishingly, the largest number produced, nearly 40,000 aircraft, was in 1944 (USSBS, Feb. 1947, p. 93, 97) – it had to draw on less experienced pilots that, third, received ever fewer hours of flight training before being thrown into battle (e.g., Pape, 1996, pp. 274-275; Levine, 1992, p. 125; USSBS, Feb. 1947, pp. 100-101; BBSU, ch. 17).

Not until the war in the air had been won and the landings in the Mediterranean and France successfully accomplished, were the heavy bombers free to exploit the victory in the air and attack in full force the centers of oil production, the centers of transport, and the other sustaining sources of military strength within the heart of Germany ... The greatest single achievement of the air attack on Germany was the defeat of the German Air Forces ... (USSBS, Sept. 1945, p. 10).

After the air war was won, the collapse of German industrial production is apparent from the data in the USSBS *Statistical Appendix to the Over-all Report* (February 1947). Production and stocks of aviation gas, motor gas, and diesel peaked and then collapsed in May, April, and April 1944, respectively.¹² Production of synthetic rubber peaked in March 1944, held about even until July and then collapsed. Production of basic chemicals (nitrogen, methanol, carbide, soda, ethylene, chlorine, sodium cyanide, sulphuric acid, and caustic soda) increased from 1939 to 1942, then held even throughout 1943, peaked in April 1944, held until July, and then collapsed. German rail traffic was fairly constant before and throughout the war until June 1944. Thereafter it rapidly collapsed. Freight car loadings grew pre-war and throughout the war, peaking in March 1944, held about even until August, and then collapsed. Crude steel production grew and peaked in the first quarter of 1943, held even until June 1944, and then collapsed. Ingot production in 1943 and 1944 was fairly constant at 2.5 million metric tons, and then collapsed as from August 1944. All the while, as noted, German arms production increased until about the same time, July of 1944, but thereafter could not be delivered to the troops anymore.

Total and marginal returns to strategic bombing

Germany’s industrial collapse may be illustrated with four figures (figures 6 to 9). Figure 6 shows allied (RAF and USAAF) bomb tonnage dropped on land transportation targets inside Germany from January 1944 to May 1945. It is obvious that the first discontinuity occurs as from September 1944. Figure 7 shows freight car loadings and net ton-km of goods moved. Again, the first discontinuity occurs with September 1944. Figures 8 and 9 therefore show data only from September 1944

onward. Figure 8 shows the month-to-month change in bomb tonnage dropped on land transportation inside Germany. Positive bars denote an increase in that month over the previous month (and vice versa). It also shows month-to-month changes in net ton-km moved. A decrease in this variable (destruction of Germany's ability to move freight) is a positive outcome from the allies' point of view and is therefore shown as a positive bar. If strategic bombing worked, one should observe that positive tonnage bars are associated with positive (destruction) bars of net ton-km moved. Moreover, for diminishing returns to hold, one should observe larger tonnage bars associated with increasingly smaller destruction bars. But that is not the case. Indeed, even when bomb tonnage fell destruction continued.

Figure 9 bears close scrutiny. In September 1944, additional tonnage dropped led to additional destruction. In October, a further increase in bomb tonnage led to a further, but smaller, increase in destruction (diminishing returns). In November, however, bomb tonnage dropped fell relative to October and yet destruction rose! In December 1944, bomb tonnage dropped increased by the largest amount (nearly 40,000 additional tons), yet destruction increased by a middling amount. In January 1945, there was a very large reduction in bombing but also a very large increase in further destruction. In February, despite a middling change in bombing, we note the largest destruction of ton-km moved. In March, a small increase in bombing leads to a small increase in destruction, and in April 1944, the largest drop in bombing is associated with a further sizable increase in destruction.

In a word, there appears to be no relation between increases in bombing and increases in the destruction of Germany's ability to move goods by rail. Moreover, while all months show rising destruction, the three months with *falling* bomb tonnage show *more* destruction than three of the five months with rising bomb tonnage. These six months lie on a negatively sloped line, suggesting – with the exception of September 1944 and February 1945 – diminishing marginal returns to bombing, at least with respect to net ton-km moved.

Similar sets of figures are available on the author's web site for aircraft acceptances,¹³ production of aviation, motor, and diesel fuel, and for an index of German chemical production. In all cases the "marginal return" graphs are odd-looking. The only – but important – caveat is that we cannot be sure about the status of the *ceteris paribus* condition. For instance, what accounts for the fall in aircraft acceptances by the German Air Force if this fall was not due to increased bombing of aircraft factories? Regrettably, with at best only eight data points at our disposal (September 1944 to April 1945), we will not be able to suggest an answer with the aid of inferential statistics. It appears that in this case one must rely on historical narrative. This narrative suggests that once the allies had obtained a superior escort fighter (the P-51, or "Mustang"), it won the air-war against German defensive and interceptor air forces; this, in turn, allowed tactical bombing in support of the invasion of Normandy, and the push across the Rhine river toward Berlin. In contrast, almost to the end, the German war economy and morale was minimally affected by strategic bombing.

Conclusions

I argue that the "strategic" bombing of Germany cleared the brush for conquest. It did not coerce Germany's leaders to surrender.¹⁴ In Levine's view, this is too harsh a judgement. "The bombers were never expected to win the war alone or avert an invasion, and they received a far lower priority than would be the case had this been planned" (1992, p. 192). Indeed, "the efforts of the tactical and strategic air forces cannot be neatly separated. Up to D-Day the tactical forces played an important

role in gaining air superiority, and in the final phase of the transportation campaign their efforts fused with those of USSTAF and Bomber Command” (p. 189).¹⁵ Despite these defenses and considerations, Levine himself concludes:

During this period [1943 and early 1944] ... the strategic forces did not accomplish their explicit assigned aims, as set out in the Casablanca and combined bomber offensive directives. They made no important contribution to the winning of the Battle of the Atlantic and did not seriously impair German morale, reduce overall German war production, or stop the manufacture of any critical items (p. 193).¹⁶

What, then, did the strategic forces achieve? In Levine’s view the marginal effects, such as delaying, but not hindering, German weapons production “would have justified strategic bombing even if it never accomplished a more positive aim. It is hard to see how any other use of Allied resources could have similarly affected the enemy in the same time period” (p. 193). This echoes USSBS’s own account: “If strategic bombing did nothing but force the dispersal of the aircraft industry it would have paid its cost” (USSBS, Jan. 1947, p. 7, pt. 10).

This conclusion must be disputed on logical grounds. The resources poured into the strategic bombing effort could surely have been applied elsewhere (e.g., more fighters devoted to air-to-air combat and in tactical support). At worst they would have had little incremental effect. In light of the eventual outcome one must venture that more tactical air power would have made a declining but positive incremental contribution to breaking through the German defensive lines in France earlier than D-Day, on 6 June 1944.

Another way to think about strategic forces is to think of them not in isolation of other inputs, but jointly. Just as targeting technology helped shift the effectiveness of strategic bombing to a higher production function, so tactical air power may be seen as a form of technology. Once the technology of tactical air power had advanced, it shifted strategic bombing onto a higher production function, only that it then became conquest bombing rather than strategic bombing in a military sense. In fairness to the allied war effort one must of course acknowledge that they suffered from severe information deficits during the war that made an assessment of the bombing’s efficacy rather more difficult. The USSBS writes (Jan. 1947, p. 2, pt. 3): “During the war it was impossible to assess the real significance of this type of warfare ... It was impossible ... to know with certainty whether or not the effects of the air activity against the Reich justified the effort expended.”

The findings presented in this paper should serve as a warning to those who advocate strategic bombing (the second Indochina war, the Persian Gulf war, the Kosovo war) on its own merits. The strategic bombing effort by the US in Vietnam was eventually given up, the allied (mostly US) bombing of Iraq in 1991 served – as in the German case – as a prelude to a land invasion, and the war in Kosovo in 1999 is the clearest example that strategic bombing without ground forces is ineffective. After all, in spite of bombing, Serbia achieved its aim of murdering or driving into refuge, civilians of Albanian descent. Moreover, public debate is skewed with apparently false images and beliefs about the efficacy of strategic bombing. These then lead to inefficient defense budget allocations by influencing current and future procurement policies. Furthermore, overinvestment in “strategic” forces probably leads to underinvestment in alternative force or, indeed, to underinvestment in diplomacy and foreign policy.

Notes

I thank participants at the First Annual Conference on Defense and Peace Economics, hosted at Rutgers University, Newark, NJ, 10-11 May 2001 for comments.

1. See Pape (1996) for a general discussion on strategic bombing. He covers 31 cases overall, and several in depth.

2. A further class is “RAF not classified.” This refers to tonnage dropped by RAF forces where the location is known (e.g., Germany, France, Italy, etc.) but the target class is unknown. This amounted to a total of about 250,000 tons of bombs.

3. The USSBS was a massive effort, involving over 1,000 people, whose purpose it was to evaluate the strategic bombing effort. More than 200 reports were produced concerning the European war, and a further 109 reports on the war in the Pacific. US personnel were moving along with US troops into liberated territories and then into Germany so as to secure original documents and interview factory managers, officials, and Nazi leaders upon capture. I have not come across any reference that throws doubt on the quality or veracity of the collected data.

The British also produced a report, the British Bombing Survey Unit (see BBSU, 1998). First published in 1947, it is of much smaller scale, often making use of data derived from the USSBS.

4. Note that although z may have been considered a random term in a war-fighting operational sense, it is not an error term in the statistical sense.

5. This is the well-known, and justly famous, report on the economic effects of strategic bombing on Germany. It was directed by John Kenneth Galbraith and included a group of young economists, e.g., Paul Baran and Nicolas Kaldor, that, along with Galbraith, would later each come to fame in their own right.

6. Although the two are often portrayed as equivalent, not all precision bombing is necessarily strategic bombing. Precision bombing can be undertaken for tactical or, indeed, for punitive purposes. But during the early wars of the war, the prevailing notion clearly was that one could hit with precision strategically important German industrial assets, and therefore undermine her war-making capabilities.

7. “In both the RAF and the United States Army Air Forces there were some who believed that air power could deliver the knockout blow against Germany, and force capitulation. This view, however, was not controlling in the overall Allied strategic plan” (USSBS, Sept. 1945a, p. 3). For example, soon after USSAF encamped in Britain in the summer and fall of 1942, they were diverted toward the North African campaign or, in early 1944, were put under Eisenhower’s command in support of tactical mission in conjunctions with preparations for the Normandy invasion. The Economic Report states that a “consideration to bear in mind is that throughout most of the period of the air war the choice of targets was greatly influenced by the requirements of the immediate military situation” (USSBS, October 31, 1945, p. 1).

Levine writes: “The hopes nursed by many people (but not the Allied leaders) during the war that bombing would avert an invasion of France and bloody land battles were disappointed, and there was a widespread, if unjustified, assumption that such a result had been expected” (1992, p. 191).

8. These figures are for 1/44 to 5/45 since bombing before 1/44 consisted of relatively small amounts.

9. Based on Overy’s work, Overy (1994), Cox (1998), and Abelshauser (1998) dispute that Germany had not fully mobilized and question that Germany’s civilian economy was unaffected. The latter view, in particular, was based on German economic reports obtained by the allies during the war that suggested that civilian production was unaffected when, in fact, an increasing share of civilian industries went toward the war effort.

10. This brings to mind Hayek’s justly famous *The Road to Serfdom*, published in 1944, in which he castigates precisely these British tendencies.

11. The two spellings of Yugoslavia are in the original.

12. There was an earlier peak in 1940 after which stocks were drawn down, in anticipation of a “short” war. When this did not materialize, production and stocks increased as from 1942 onward.

13. German aircraft *production* increased, but *acceptances* of aircraft by the German Air Force eventually fell. What is relevant for the prosecution of the war is of course the latter.

14. Pape writes that Germany feared a Soviet invasion more than invasion by the western allies and hence fought “to buy time to permit soldiers and civilians to flee the advancing Red Army” (1996, p. 302). This is not convincing as Germany could simply have surrendered on the western front while maintaining an eastern front until the western allies had completed its invasion all the way to the Polish border.

15. At this point the United States Army Air Force (USAAF) had been renamed the United States Strategic Air Force (USSTAF).

16. The Casablanca directive of January 1943 combined the until-then separate efforts of RAF and USAAF.

List of references

Abelshauser, Werner. “Germany: Guns, Butter, and Economic Miracles,” pp. 122-176 in Mark Harrison (ed.) *The Economics of World War II: Six Great Powers in International Comparison*. Cambridge: Cambridge University Press, 1998.

British Bombing Survey Unit (1998). *The Strategic Air War Against Germany, 1939-1945: Report of the British Bombing Survey Unit*. With forewords by Michael Beetham and John W. Huston and introductory material by Sebastian Cox. London: Frank Cass Publishers.

Cox, Sebastian (1998). “The Overall Report in Retrospect,” pp. xxiii-xli in British Bombing Survey Unit (1998). *The Strategic Air War Against Germany, 1939-1945: Report of the British Bombing*

- Survey Unit*. With forewords by Michael Beetham and John W. Huston and introductory material by Sebastian Cox. London: Frank Cass Publishers.
- Daniels, Gordon (1981). *A Guide to the Reports of the United States Strategic Bombing Survey. I Europe. II The Pacific*. London: Royal Historical Society.
- Levine, Alan J. (1992). *The Strategic Bombing of Germany, 1940-1945*. Westport, CT: Praeger.
- Overy, Richard (1994). *War and Economy in the Third Reich*. Oxford: Oxford University Press.
- Pape, Robert A. *Bombing to Win: Airpower and Coercion in War*. Ithaca, NY: Cornell University Press, 1996.
- United States Strategic Bombing Survey, USSBS (September 30, 1945). *Over-all Report (European War)*. Washington, DC: USSBS.
- United States Strategic Bombing Survey, USSBS (September 30, 1945a). *Summary Report (European War)*. Washington, DC: USSBS.
- United States Strategic Bombing Survey, USSBS (October 31, 1945). *The Effects of Strategic Bombing on the German War Economy*. Washington, DC: USSBS.
- United States Strategic Bombing Survey, USSBS (January 1947). *Aircraft Division Industry Report*. 2nd edition. Washington, DC: USSBS.
- United States Strategic Bombing Survey, USSBS (February 1947). *Statistical Appendix to Over-all Report (European War)*. Washington, DC: USSBS.

Appendix: Germany: Land transportation graphs

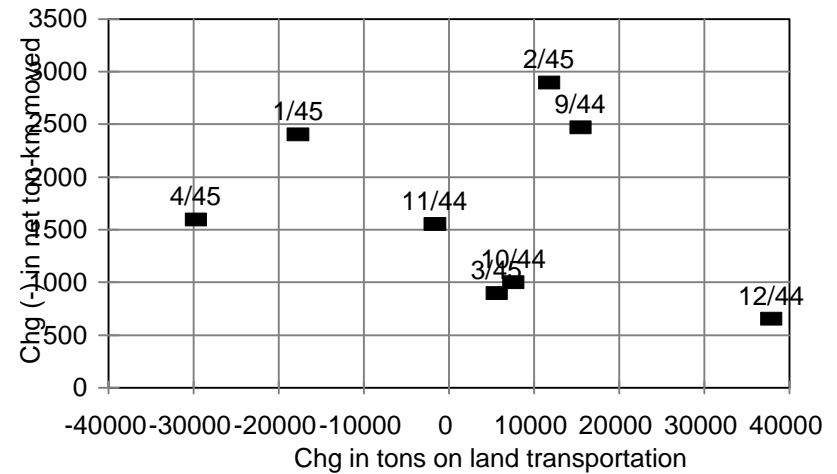
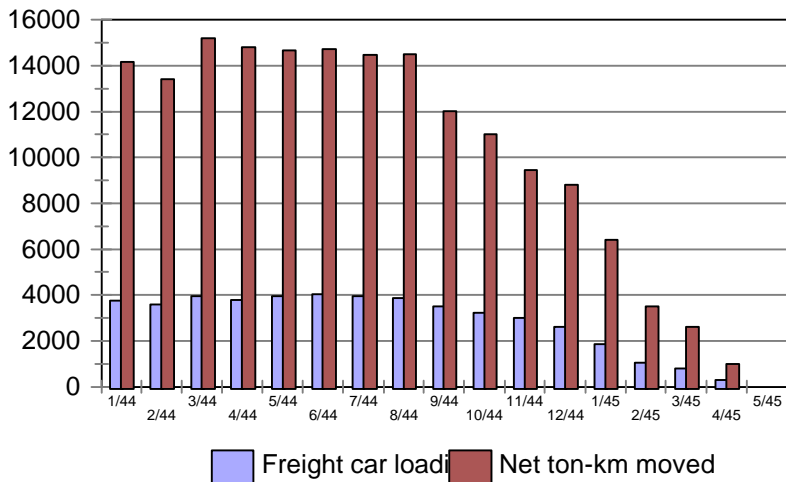
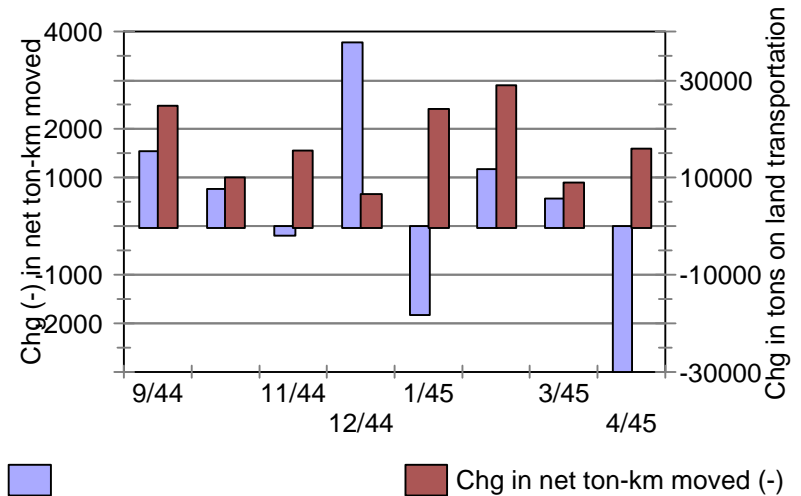
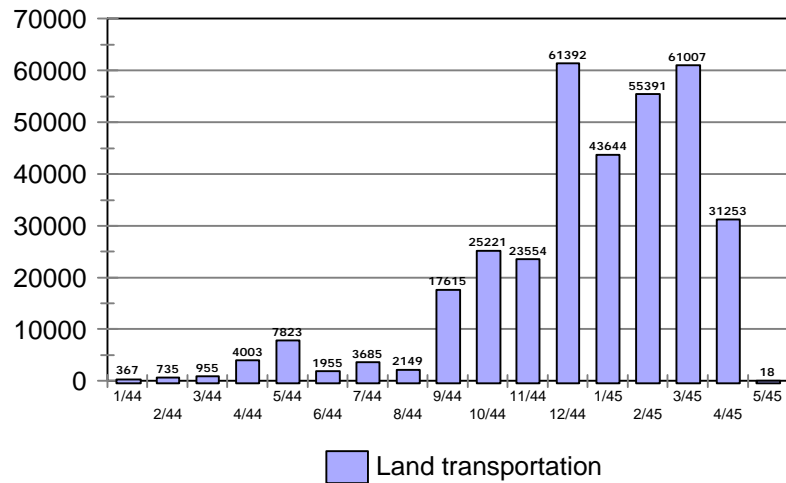


Figure 7: Freight car loadings and net ton-km moved

Figure 9: Land transportation targets; marginal returns