

The Volume of Soviet Munitions Output, 1937–1945: A Reevaluation

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The only official measure of overall Soviet munitions output in World War II, first published in 1965, was based on changes in values, not volumes, and grossly understates change in the level of real Soviet war production. Subsequently published official data on production of ground and air munitions in physical units, supplemented by information about real spending on naval munitions, provide foundations for a new index. During the war the USSR produced more munitions than Great Britain or Germany, but much less than the United States.

The only available summary measure of the total Soviet output of munitions in World War II is an index first published in 1965, in the sixth, final volume of the *Istoriia Velikoi Otechestvennoi voiny Sovetskogo Soiuz, 1941–1945* [History of the Great Patriotic War of the Soviet Union, 1941–1945], hereafter called the *Istoriia* index. It covered the years from 1940 to 1944 and was said to be based on the output of the four main commissariats supplying the ground and air forces—the aircraft, tank-building, armament, and ammunition industries. Published with it were subindices showing the output of each of the four commissariats separately for the years from 1940 to 1945. The *Istoriia* index and its four subindices are reproduced in Table 1.

The *Istoriia* index was probably first compiled during or immediately after the war. It showed that the output of Soviet ground and air munitions at the 1944 peak stood at 251 (1940 equals 100). This formed the basis for N. A. Voznesenskii's statement in 1947 that "war production in the eastern and central areas of the USSR alone increased during the Patriotic War two and a half times over in comparison with the 1940 production level for the whole of the USSR."¹ After Voznesenskii's book about the war economy there was a blackout on the publication of

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¹ N. A. Voznesenskii, *War Economy of the USSR in the Period of the Patriotic War* (Moscow, 1948), p. 63.

TABLE 1
THE *ISTORIIA* INDEX OF SOVIET MUNITIONS OUTPUT, 1941-1945
(1940 = 100)

Year	<i>Istoriia</i> Index	Industrial Commissariat			
		Aircraft	Tank-Building	Armament	Ammunition
1941	140	126	112	145	152
1942	186	178	184	191	218
1943	224	223	234	200	264
1944	251	239	296	206	310
1945		177	276	156	171

Source: *Istoriia Velikoi Otechestvennoi voiny Sovetskogo Soiuza, 1941-5* (Moscow, 1965), vol. 6, pp. 45, 52.

further statistical information from the war period, which explains the long delay in full publication of the *Istoriia* index.

The *Istoriia* index has continued to be republished in official statistical handbooks and to be cited as authoritative to the present day. (In subsequent publications the *Istoriia* index has often been represented as an index of total munitions output rather than of the main types of ground and air munitions.) Soviet writers have never questioned its reliability as a guide to Soviet munitions output in wartime.

It is, however, far from clear what these index numbers were meant to measure. Whatever else, it is certain that they *do not* satisfactorily measure quantities of weapons produced. Detailed time series for different lines of war products, denominated in physical units, have been published subsequently in the official twelve-volume *Istoriia Vtoroi Mirovoi voiny, 1939-1945* [History of the Second World War, 1939-1945].² These make it absolutely clear that the *Istoriia* index numbers greatly understate the growth of munitions production from the beginning of the war to the wartime peak in 1944.

For example, four times as many military aircraft were produced in 1944 as in 1940, compared with the peak output of 2.4 times the 1940 level recorded by the *Istoriia* index for the aircraft industry. A larger discrepancy is found in the case of armored fighting vehicles; more than ten times as many units were produced in 1944 as in 1940, while the industry's *Istoriia* index grew to only three times. The armament industry's *Istoriia* index for 1944 stands at only twice the 1940 level, yet six times as many heavy guns were produced in 1944 as in 1939. Light guns were nearly eight times the 1939 level even though more guns were manufactured then than in 1940. The 1944 output of machine pistols was 24 times the 1940 level, that of machine guns three times, and only the

² See relevant sections of *Istoriia Vtoroi Mirovoi voiny, 1939-1945* (hereafter *IVMV*) (Moscow, 1973-82), vols. 1-12. Detailed series of physical output are brought together from this and other sources in Mark Harrison, *Soviet Planning in Peace and War, 1938-1945* (Cambridge, 1985), pp. 250-52.

increase in supply of rifles and carbines falls below the index. As for ammunition, the official *Istoriia* index shows 1944 output to be three times the 1940 level, but this is somewhat less than the increase in the supply of shells and mines recorded for 1944 over 1941; the output of shells taken separately had expanded to more than nine times 1940 output already by 1943.

Discrepancies on this scale and pattern cannot possibly be explained by changes in either the composition or the quality of Soviet munitions produced in wartime. Only in the aircraft industry was there any shift away from bigger, more complex and expensive types of output to cheaper types, and the scale of the shift was too slight to account for more than a small part of the gap between change in numbers produced and change in the industry's subindex. Overall, the quality of Soviet munitions rose during the war, and should have further boosted the valuation of real munitions output above any measure based on crude numbers of products.

The physical product series provide the basis for a revised index of the volume of total Soviet finished output of munitions. First, however, I wish to explain the character of the *Istoriia* index of total output and the four industry subindices.

THE *ISTORIIA* INDEX

There are two problems with the *Istoriia* index: prices and coverage. First, what price set was used to compile it? The context of its first publication made it look like a volume index calculated at fixed prices, although nothing was said in writing. It was entered in a table as a subindex of gross industrial production (normally measured for this period at the so-called fixed prices of 1926/27), alongside various other indicators of wartime economic activity, for the most part denominated in fixed prices (such as national income, measured at "1926/27" prices) or in physical terms (millions of people in employment). Yet we have seen that the expansion of the *Istoriia* index lags too far behind the reported growth in physical output of war products for it to be understood as a measure of volumes.³

Second, what was the *Istoriia* index intended to cover? It was originally published in the form of a weighted sum of the four subindices for the industries supplying aircraft, tanks, guns, and ammunition. This too may have been misleading.

If the *Istoriia* index is really the weighted average of the four subindices, then there must be a mistake in the reported totals. Simple algebra shows that the behavior of the *Istoriia* index as reported cannot

³ Previously I considered various possible explanations—that the *Istoriia* index was based on changes in values, not volumes, or that its behavior was seriously affected by changing boundaries in the administration of war production. See Harrison, *Soviet Planning*, pp. 119–21.

TABLE 2
NKO EXPENDITURE ON MUNITIONS AND THE *ISTORIIA* INDEX COMPARED,
1938-1945

	<i>Istoriia</i> Index		<i>Finansovaia sluzhba</i> Index of NKO Expenditure on Munitions at Current Prices	
	Original	Recalculated to show 1944 = 100	Original	Recalculated to show 1944 = 100
1938			100.0	15.1
1939			177.6	26.9
1940	100	40	217.9	33.0
1941	140	56	361.2	54.6
1942	186	74	507.5	76.8
1943	224	89	591.0	89.4
1944	251	100	661.2	100.0
1945			471.6	71.3

Notes and sources: For the *Istoriia* index, see Table 1. For the *Finansovaia sluzhba* index, see *Finansovaia sluzhba Vooruzhennykh Sil SSSR v period voiny* (Moscow, 1967), p. 66. When the *Istoriia* index is regressed against the NKO expenditure index over the years from 1940 to 1944, with the latter as the independent variable, the regression is highly significant, and the constant term is not significantly different from zero at the 10 percent level. When the constant term is dropped, the regression is significant, and the regression coefficient is insignificantly different from one, at almost any meaningful level.

in fact be explained by the variation in the four subindices. One possible way out of the inconsistency would be to assume an error somewhere, whether deliberate or typographic. The likeliest candidate for a mistake is the 1941 entry of the *Istoriia* index, which is too high.⁴ This hypothesis is attractively simple, but I reject it in favor of the following alternative.

The four subindices are measures of defense industry production, but the *Istoriia* index measures munitions expenditure. The coverage of production was less comprehensive than that of expenditure. Expenditure was measured at current prices, production at the so-called unchanged prices of 1926/27.

What is the evidence for this? Table 2 compares the *Istoriia* index, recalculated with 1944 as the base year, with an official index of defense commissariat (NKO) expenditure on munitions at current prices; this

⁴ The entries of the total index for 1940 to 1943 can be taken as the right-hand sides of four simultaneous equations, with the four 1940 weights of the subindices as unknowns. In this case there is no set of nonnegative solutions which can satisfy the constraints. Moreover, the entry for total munitions output in 1944 of 251 cannot be matched by combining the subindices using weights imputed in this way. When the entries of the total index for 1940 and 1942-1944 are taken as the right-hand sides of the four simultaneous equations, again with the four 1940 weights of the subindices as unknowns, feasible and realistic weights result, but now the entry for total munitions output in 1941 is estimated at 130, not the 140 given. This might be consistent with a typographic or arithmetic error in the official index for 1941. The "feasible and realistic" 1940 weights are: aircraft—45 percent, tanks—23 percent, guns—23 percent, ammunition—9 percent.

excludes only naval munitions, procured by the commissariat for the war fleet (NKVMF). Except in 1940/41, the two indices move almost exactly in step.⁵ The fit is too good to be a coincidence, even though I cannot explain the 1940 gap.

I think it likely, however, that the four subindices were based on production. While the behavior of the *Istoriia* index can be clearly associated with a published expenditure series, the same is not true for the four subindices.⁶ They were explicitly classified by commissariat, that is, by production branch. Even if the underlying price set were the same, the difference between a production classification and an expenditure classification would be sufficient to explain some discrepancy between the four subindices and the *Istoriia* index.⁷

At what prices were the four subindices calculated? It is certain that they were not compiled using genuinely fixed prices, but this still leaves two alternatives—current prices, and the prices of “1926/27.”

It is possible that the four subindices measure reported output at current prices. The *Istoriia* index and the subindices diverge, but their divergence from each other is arithmetically small and is far less than their common divergence from series for reported physical output of munitions. Therefore the subindices could have employed a price set similar to the *Istoriia* index, that is, transfer prices at current rubles. The discrepancy between them could be due entirely to the various sources of a production-expenditure gap.

More likely, however, are “1926/27” prices. In theory these were product prices actually prevailing in 1926/27 or, for new products introduced after that year, notional prices based on 1926/27 factor costs. However, new products were actually incorporated into the “1926/27” price set at current prices, not the prices which would notionally have prevailed in 1926/27.⁸ Moreover, in munitions at least, the replacement of old products by new ones was quite rapid; as a result, by 1940 there

⁵ This was drawn to my attention by Peter Wiles. I owe him special thanks for giving me access to the rare and invaluable *Finansovaia sluzhba Vooruzhennykh Sil SSSR v period voiny* [Financial service of the USSR Armed Forces in the period of the war] (Moscow, 1967), from which this and other evidence is derived.

⁶ The four subindices shown in Table 1 are not significantly associated with indices of current NKO expenditure on munitions under comparable headings, 1941–1945, based on budget outlays derived by Frank Doe, “Understanding the Soviet View of Military Expenditures” (Washington, DC, 1982), table 4.

⁷ Reported munitions output (Q) and expenditure (E) could be expected to diverge because of defective products included in reported output but remaining unsold (DP), because of civilian products of defense factories counted in output of munitions branches of industry (CIV), and military products of civilian industries not counted in munitions output but purchased as munitions out of the defense budget (MIL), because of exports (EX) and imports (IM), and because of the lag between production and procurement:

$$E_n = Q_{n-1} - DP_{n-1} + (MIL_{n-1} - CIV_{n-1}) + (IM_n - EX_n)$$

⁸ Naum Jasny, *The Soviet Price System* (Stanford, 1951), pp. 96–97.

were probably no products included in the "1926/27" price set which were actually priced in 1926/27. Thus the prices of "1926/27" amounted in reality to no more than a kind of moving average of new product prices over a past interval of variable length. The more rapid the diffusion of new products, the more closely would "1926/27" prices approximate to current prices. Prewar evidence suggests that product innovation and diffusion were sufficiently rapid in the Soviet engineering industry to make current and "1926/27" prices virtually indistinguishable.⁹

In summary, the *Istoriia* index is based on the current ruble value of defense commissariat total expenditure on ground and air munitions. The four subindices which accompanied it are production indices covering a substantial subset (but not all) of the munitions subject to NKO procurement. The subindices may have been calculated at current prices or, more likely, at "1926/27" prices which, in the case of munitions and other products of engineering, may have come to nearly the same thing.

MUNITIONS PRICES IN WARTIME

If values lagged behind volumes, then ruble prices of Soviet munitions must have fallen substantially in wartime. Here is something that we know about. Munitions prices were already being pushed down when war broke out. Downward pressure intensified during the war when trade commissar and Deputy Prime Minister A. I. Mikoian was appointed in March 1942 to check the dizzying rise in ruble costs of NKO procurements. He found multiple prices for identical products and huge price-cost margins in which NKO officials acquiesced. Meanwhile unit costs in the munitions industries were falling smartly, mainly because of the transition to serial production.¹⁰

The most comprehensive information on trends in munitions prices appears in Soviet estimates of cost savings accruing to the munitions budget in each year of the war as a result of buying current output at current prices rather than prices of the previous year. These can be compared with each year's total cost of munitions procurement to yield a chained Paasche index of prices for ground and air munitions, shown in Table 3. An index of naval munitions prices, chained back to 1941 equals 100, is also shown in Table 3. These indices confirm significant, sometimes dramatic price reductions for Soviet munitions in every year of the war and suggest that the general decline in munitions prices was of the order of 40 percent.¹¹

⁹ Donald R. Hodgman, *Soviet Industrial Production, 1928-1951* (Cambridge, MA, 1954), pp. 9-11.

¹⁰ *Finansovaia sluzhba*, pp. 78-79.

¹¹ Abram Bergson, *The Real National Income of Soviet Russia Since 1928* (Cambridge, MA, 1961), p. 74 and appendix E, reckoned 1944 munitions prices at above the 1942/43 level and only

TABLE 3
SOVIET PRICE DEFLATORS AND REAL MUNITIONS EXPENDITURE, 1940-1945

	Price Deflators		Real Expenditure on Ground and Air Munitions
	Ground and Air Munitions	Naval Munitions	
1940	100.0		100.0
1941	84.5	100.0	196.2
1942	65.8	86.0	354.2
1943	60.4	79.1	448.9
1944	59.0	75.2	514.3
1945	56.8		380.8

Notes and sources: For Price Deflators, see the Appendix. For Real Expenditure, see index of NKO expenditure on munitions at current prices (Table 2), recalculated to show 1940 equals 100, divided by the appropriate price index.

According to an official calculation, the total accumulated saving from price reductions through the war years amounted to 50.3 billion rubles.¹² This is comparable to a saving of 51.0 billion rubles which can be estimated from Table 3 when we take 1941 (rather than 1940) as the base year and calculate the cumulative sum saved on NKO procurements through to the end of May 1945.¹³

These indices are also in the same general range as more fragmentary data compiled on an unknown basis, and released by Voznesenskii after the war. For example, according to the latter, the prices of defense industry products had fallen in 1942 to 72 percent of the 1940 level (as against a figure of 65.8 shown in Table 3).¹⁴ For 1940 to 1943, Voznesenskii reported figures suggesting a cumulative 42.6 percent fall in unit costs in machine building and metal working (that is, military and civilian engineering), compared with the estimated 39.6 percent fall in munitions prices shown in Table 3.¹⁵

The behavior of Soviet munitions prices, estimated in this way, was sharply at variance with other price trends. Some relevant comparisons are as follows. By 1944 wholesale prices of civilian machinery, of basic industrial goods, and of fuel and power were slightly above the 1940 level; railway charges per ton-kilometer had risen by a quarter.¹⁶

20 percent below the 1940 level. This figure seems arbitrarily conservative. Also arbitrary, but in the other direction, is the estimate of P. Krylov, "Bor'ba za ekonomii v voennye gody" [The struggle for economy in the war years], *Planovoe khoziaistvo*, 3 (1985), p. 34; he suggests that during the war the wholesale prices of "the most important types of weapons and ammunition" fell by more than half.

¹² *Finansovaia sluzhba*, p. 87.

¹³ This means the sum of $[(E_n/P_{1941}) - E_n]$ in each year from 1942 to 1944, plus five-twelfths of $[(E_n/P_{1941}) - E_n]$ for 1945 (for notation, see the Appendix).

¹⁴ Voznesenskii, *War Economy*, p. 102.

¹⁵ *Ibid.*, p. 108.

¹⁶ Independent estimates reported by Bergson, *Real National Income*, pp. 350, 367-68.

Monthly ruble earnings of industrial workers were more than 50 percent above the prewar benchmark.¹⁷ As for the cost of living faced by public sector employees, it stood in 1944 at almost six times the prewar price level.¹⁸

Possibly there was some cheating involved in the munitions price cuts claimed. Certainly this was Naum Jasny's belief.¹⁹ Some reductions may have been achieved at the expense of unpaid overtime and subsidies to defense producers and suppliers to the defense industries. At the same time, even taking into account rising wages and nonlabor input costs, the suggested decline in unit procurement prices was not at all implausible. It is supported both by claimed reductions in unit labor requirements of individual weapons, and by claimed improvements in finished output per worker in the munitions sector.²⁰ Nor are these Soviet claims out of line with international experience in World War II.²¹

The official index of reported NKO expenditure on munitions (Table 2) can be divided by the ground and air munitions price index (Table 3). The result is a chained Laspeyres index of real expenditure on ground and air munitions. In 1944 it stands at roughly 5.1 times 1940 expenditure.

We can almost certainly do better than this, however, by producing a new index of the volume of total munitions produced. We can base it on available physical product series and published information about ruble weapons prices and expenditure shares in different years. We can take into account the fluctuating supply of naval munitions—the only line of

¹⁷ Voznesenskii, *War Economy*, p. 94.

¹⁸ Eugène Zaleski, *Stalinist Planning for Economic Growth, 1933–1952* (London, 1980), p. 452 (table 118, row 22).

¹⁹ Jasny, *The Soviet Price System*, p. 107.

²⁰ For reductions in labor requirements of Soviet weapons from 1941 to 1943, see Voznesenskii, *War Economy*, p. 92; according to *Istoriia Velikoi Otechestvennoi voiny Sovetskogo Soiuz, 1941–1945* [History of the Great Patriotic War of the Soviet Union, 1941–1945] (Moscow, 1965), vol. 5, p. 375, finished output per worker in Soviet defense industries rose by 121 percent between May 1942 and May 1945.

²¹ In the United States, contract prices for the War Department, Army Air Force, and Ordnance fell by 25 to 40 percent in three and a half years (January 1942–August 1945), despite a 50 percent increase in weekly earnings in manufacturing industry (data reported by Bergson, *Real National Income*, pp. 373–74). Behind this lay a doubling of output per worker in munitions in just two years, 1942–1944, with only a small increase in the length of the working week. (According to charts published in *American Industry in War and Transition, 1940–50*, Part II: *The Effect of the War on the Industrial Economy* [Washington, DC, 1945], p. 10, “productivity” [whether per worker or per hour worked is not specified] in munitions industries in 1944 stood at approximately two and one-half times the 1942 level, while average hours worked in durable goods manufacturing rose over the same two years from roughly 45 to 47 hours.)

In Germany, too, output per munitions worker doubled between 1941 and 1944, without any increase in hours worked. German munitions output trebled between the end of 1941 and mid-1944; see *Die deutsche Industrie im Kriege, 1939–1945* (Berlin, 1954), p. 191. Meanwhile, between mid-1941 and mid-1944 the German munitions work force grew by only 44 percent (from 2.7 to 3.9 millions), according to Burton H. Klein, *Germany's Economic Preparations for War* (Cambridge, MA, 1959), p. 217.

Soviet defense output to decline during the war years. We can also examine the sensitivity of these estimates to whether "early" or "late" prices and values are used to weight the index.

RELIABILITY OF PHYSICAL PRODUCT SERIES

Before arriving at a new munitions index, we have to satisfy ourselves as to the reliability of its statistical foundations. How trustworthy are the available time series for physical output of tanks, planes, guns, and shells?

A Soviet historian, B. V. Sokolov, has recently expressed distrust on the following grounds. Assuming their reliability, Soviet production figures for combat aircraft and armored fighting vehicles may be used in combination with data on Soviet combat stocks and imports to estimate Soviet losses of these munitions in each period of the war.²² Sokolov then compares Soviet equipment losses estimated in this way with German losses on the eastern front. He finds that estimated Soviet losses far exceeded German losses over equivalent periods, regardless of whether Soviet forces were losing or winning the war, often by a factor of two or three to one, occasionally by more.

Sokolov ascribes a part of the excess of estimated Soviet over German losses to the same Stalinist deformations in the military sphere which were associated with heavy expenditure of soldiers' lives—excessive centralization and despotic use of authority, unthinking obedience, the low valuation of life itself in the wake of the mass repressions of the 1930s. He judges, however, that it is impossible to ascribe all the estimated disproportion to such factors. He believes the Soviet losses estimated in this way are implausibly high and concludes that the fault lies with the underlying production data, which must be exaggerated. The contribution to Soviet victory of the Soviet munitions industries should be downgraded (and that of the Soviet military should presumably be upgraded correspondingly).

I find this chain of reasoning doubtful. There are significant problems of methodology involved in the estimation of losses by Sokolov's route, but they are not conclusive.²³ For the sake of argument, therefore, let us

²² B. V. Sokolov, "O sootnoshenii poter' v liudiakh i boevoi tekhnike na Sovetsko-Germanskom fronte v khode Velikoi Otechestvennoi voiny" [On the correlation of losses of people and combat equipment on the Soviet-German front in the course of the Great Patriotic war], *Voprosy istorii*, 9 (1988), p. 123. Define CS_n as the level of combat stocks at the end of period n , and assume that there are no other stocks held in the rear or in reserve; the number of units produced during each period is given by Q_n , imported units by IM_n , and the number of losses by L_n . Then the following would obtain:

$$L_n = Q_n + IM_n - (CS_n - CS_{n-1})$$

²³ Hidden assumptions are made about initial reserves and rear formations, and the change in their level in each period of account, and about noncombat losses. At the same time it is true that

take for granted that when Soviet munitions losses are estimated on the basis of production series they look disproportionately high. Is this unbelievable?

Modern Soviet military commentators do not find disproportionate rates of combat expenditure of Soviet munitions in World War II implausible. In one view, the Red Army wasted its armored resources as a result of strategic and logistic errors. Excessive losses arose in the early period of the war because of the incorrect use of tanks, deficiencies of leadership, and the lack of spare parts. The wasteful deployment of tank units continued through 1942; even after 1943, when fully motorized and independently operating tank formations were created, they continued to be used inappropriately, for example, for assaults on large cities, right through 1945. As a result, "the Soviet tank forces suffered impossibly heavy losses throughout the war."²⁴

German evidence supports the proposition that Red Army aircraft were easier to shoot down than those of the RAF and USAAF, and not only in June and July 1941. In 1942 Hitler decorated Adolf Galland, the Luftwaffe fighter ace, considering that his 94 air victories "were achieved exclusively against the western enemy and were therefore to be valued more highly." Galland himself described the Soviet losses as "astronomical," and sustainable only because of the remoteness of the Soviet centers of aircraft production: "It was as if one tried to exterminate a nest of ants by killing them one by one without being able to get to their heap."²⁵ In 1943/44, when the war in the air was at its most intense, the Luftwaffe "used Russia as a school for inexperienced

the possibility of bias introduced as a result of hidden assumptions may diminish with the length of the accounting period. In the long run both imports and changes in combat and reserve stocks were small relative to output, and it is output which therefore dominates (in an accounting sense) the determination of losses. Over the period of the war taken as a whole, these are unlikely to be significant sources of bias. The relative importance of combat and noncombat losses, however, will remain undetermined. For further discussion of this methodology, see Harrison, *Soviet Planning*, pp. 110–15, 256–66, where Soviet wartime losses of combat aircraft, armored fighting vehicles, and guns are similarly estimated.

²⁴ Vitalii Shlykov, "On the History of Tank Asymmetry in Europe," *International Affairs* (Moscow), 10 (1988), pp. 112–13. My thanks to Julian Cooper for this reference. Shlykov's assessment that the Soviet Army possessed a numerical advantage in tanks over the Wehrmacht on the eve of war has been subjected to detailed criticism by V. P. Krikunov, " 'Prostaia arifmetika' V. V. Shlykova" [The 'simple arithmetic' of V. V. Shlykov], *Voenna-istoricheskii zhurnal*, 4 (1989), pp. 41–44. The part of Shlykov's argument which is significant for this article rests in part on direct military estimates of average monthly permanent losses of aircraft, tanks, and guns on the front line, detailed in *Voennaia strategiiia* [Military strategy] (Moscow, 1963), p. 427, as follows: aircraft—21 percent, tanks—19 percent, guns—9 percent. It is true that these are substantially lower than the equivalent rates implied by Sokolov and estimated by Harrison, *Soviet Planning*, p. 265, using the same methodology as Sokolov. It is possible, however, that the military estimates refer only to combat losses.

²⁵ Adolf Galland, *The First and the Last* (London, 1970), pp. 71, 91. My thanks to Robin Clifton for this and the following reference.

pilots. There they could build flying and fighting skills before being thrown into the cauldron of western air battles."²⁶

Sokolov, however, does not believe his own estimates of Soviet munitions losses; he considers them too high. He believes that numerical advantage must have reduced Soviet losses below the German level after 1942. If estimated losses are too high, the reason must be that reports of munitions output were exaggerated. He considers production exaggerated first of all at the enterprise level:

Inflated reports [*pripiski*]²⁷—a defect inherent in our national economy as in the prewar, so in the postwar period, were apparent also in wartime when obligations were often handed down to enterprises subject to shortage of resources for their fulfilment and without taking account of real possibilities. The arbitrary administrative principle was triumphant, and on the fulfilment of these often unbalanced plans hung the fate, in the literal sense of the word, of enterprise leaders. Under such circumstances inflated reports were an inevitable evil.²⁷

I do not agree. I tend to evaluate positively the reliability of Soviet data for munitions output in physical units for two reasons. First, a military inspectorate was already installed in Soviet defense factories in 1939, charged with control over both quantity and quality of munitions output.²⁸ This system of "consumer sovereignty," unique to the munitions industries in the Soviet economy, made it much more difficult for the defense factory to record fictitious output than for its counterpart in the civilian sector. Military inspection could be so strict, on occasion, as to prove an independent factor delaying the handing over of finished output and accentuating munitions shortages in wartime.²⁹

Second, there was no obvious reticence of enterprises and ministries when plans failed, even in the most critical months of 1941/42. Plan failure was reported, not concealed. Underfulfillment of quarterly and monthly plans for shell production by wide margins was reported period by period in the second half of 1941. By December 1941 the reported output of aircraft was down to two-fifths of ministerial targets, and that of aircraft engines was down to one-quarter.³⁰ Such reports are inconsistent with the view that industrial leaders inflated output returns to show 100 percent plan fulfillment because their lives depended on it.

"We all know that the assignments are impossible," wrote one participant; "if they can be met only by 75 percent, there will be

²⁶ Williamson Murray, *Luftwaffe: Strategy for Defeat, 1933–1945* (London, 1988), p. 371.

²⁷ Sokolov, "O sootnoshenii poter'," p. 125.

²⁸ *IVMV*, vol. 2, p. 189; Julian Cooper, "Defence Production and the Soviet Economy, 1929–1941," Soviet Industrialisation Project Series no. 3 (University of Birmingham, 1976), pp. 26–27.

²⁹ A. P. Kovalev, "V Gosplane v to pamiatnoe vremia" [In Gosplan in that memorable time], *EKO*, 5 (1988), pp. 22–23, reports the case of a nonferrous metal works where, in the early months of the war, delays in military inspection of ammunition cases aggravated the already severe shell famine.

³⁰ *IVMV*, vol. 4, pp. 150–51.

rejoicing and bonuses and Orders of Merit.”³¹ In fact, some of the most important peacetime obstacles to the reporting of true output were absent. Norms and targets were set, but workers and managers alike were praised and rewarded for producing as much as possible, not for mechanically fulfilling the plan. Underfulfillment of the plan generated less disgrace than slacking and working below capacity. Mechanically fulfilling the plan did not guarantee immunity from inspection.³² Traditional incentives to falsify reports may have been to some extent neutralized.³³

Clearly, many Soviet wartime economic series need revision, but I would be surprised if data for physical output of munitions required radical surgery. I am inclined to see them as a relatively reliable foundation for what follows.

FIVE NEW SUBINDICES

The first result of the revision process is five new indices covering the wartime supply of aircraft, armored fighting vehicles (AFV), armament and ammunition from 1940 to mid-1945, and naval munitions from 1940 to 1945. They can also be extended back to 1937, accepting somewhat lower standards of coverage, detail, and reliability. (Sources and methods are further summarized in the Appendix and detailed in a statistical supplement available from the author.)

The period beginning in 1940 is the best-documented one as far as munitions output in physical units is concerned, and it gives correspondingly reliable results in terms of index numbers.

For 1940 and the war years, I use three different methods. Available time series for physical output of aircraft, AFV, and armament are valued on the basis of 1941 munitions prices and added up to give series for total finished output of the industrial branch in 1941 rubles. The process is repeated using 1944 munitions prices. When divided by base-year output, the result is two indices, one set to 1941 equals 100 and the other set to 1944 equals 100.

In the case of ammunition, no prices are available for either 1941 or 1944; the only near-continuous time series denominated in physical units for the war years shows the supply of “shells and mines.” I assume this series to be representative of ammunition supply as a whole. Therefore, the problem of weighting and adding up different series does not arise at this stage. Indices are generated with both 1941 and 1944 as base years, but the difference is purely formal.

³¹ G. S. Kravchenko, *Ekonomika SSSR v gody Velikoi Otechestvennoi voiny (1941–1945 gg.)* [The economy of the USSR in the years of the Great Patriotic War (1941–1945)] (Moscow, 1970), pp. 410–11.

³² See V. V. Kolotov, *Nikolai Alekseevich Voznesenskii* (2nd edn., Moscow, 1976), p. 267.

³³ David Dyker, review of Harrison, *Soviet Planning*, in *Slavonic and East European Review*, 75 (1987), p. 309.

For naval munitions we face a choice between an index based on numbers of warships of the "basic classes" (that is, excluding mosquito craft) completed in each year, or an index of current expenditure deflated by a chained index of procurement costs which can be reckoned in terms of a base year either in 1941 or in 1944. For various reasons I prefer the method of expenditure deflation.

The choice of naval index is awkward and makes quite a lot of difference. The published series for warships of the basic classes shows a continuous, year-by-year, dramatic fall in vessel completion from 41 in 1941 to only 4 in 1944. In contrast the index of deflated naval munitions expenditure shows a substantially lower level of procurement in 1941/42 compared to 1940, then near-recovery by 1944.

In principle I would prefer unambiguous physical product series to expenditure series, however accurately deflated, for the foundations of a revised munitions index. In this case, however, I prefer deflated expenditure. The disastrous fall in warship completions would certainly be misleading as a measure of both naval munitions consumption and supply. Although the Soviet war fleet played no strategic role in World War II, it played a major tactical role, especially in support of the ground forces. At some moments this tactical role could be decisive. In the winter of 1941, for example, the Baltic fleet's artillery was central to the defense of Leningrad. The acquisition of new ships became less important than their supply with naval guns, ammunition, and other means of war. The latter are captured by the method of expenditure deflation, but would be lost otherwise (for example, the artillery series used for my new "Guns" subindex in Table 3 explicitly excludes naval guns).

It may be that imports sustained 1944 expenditure on naval munitions above the level of domestic production. This is undoubtedly true, but I do not believe the effect to be very significant. The share of vessels (including merchant vessels, not chargeable to war-fleet expenditures) in the dollar value of United States Lend Lease shipments in 1944 was less than 6 percent.³⁴ This was similar to the navy's share in overall munitions outlays, and it suggests that any overstatement of naval munitions production in 1944 arising from the use of deflated expenditure will be minor.

The new subindices for 1940 to 1945 are shown in Table 4. Also shown in the table are results of their extension back to 1937. Index numbers given for the period before 1940 are certainly less reliable than for the war years themselves. Before 1940 three of the five subindices (aircraft, AFV, and ammunition) rely on a single series showing units produced under some heading which is assumed to be representative, and the aircraft series is inflated in the early years by inclusion of civilian types.

³⁴ Harrison, *Soviet Planning*, p. 259.

TABLE 4
NEW SUBINDICES FOR FINISHED OUTPUT OF GROUND, AIR, AND NAVAL
MUNITIONS, 1937-1945

	Aircraft	Armored Fighting Vehicles	Guns	Ammunition	Naval Munitions
At Constant Prices of 1941					
1937	29	15	13	13	58
1938	36	21	30	32	64
1939	68	28	44	29	92
1940	69	26	43	36	131
1941	100	100	100	100	100
1942	141	381	282	190	89
1943	186	375	288	310	113
1944	218	465	280	326	124
1945	219 ^a	501 ^a	260 ^a	287 ^a	161
At Constant Prices of 1944					
1937	13	3	5	4	46
1938	16	5	12	10	52
1939	30	6	17	9	74
1940	31	6	16	11	106
1941	46	22	38	31	81
1942	64	82	102	58	72
1943	84	81	104	95	91
1944	100	100	100	100	100
1945	101 ^a	108 ^a	93 ^a	88 ^a	130

^a First six months, at annual rate.

Source: See the Appendix.

Only the armament index maintains relatively full coverage before as after 1940.

The prewar subindex for naval munitions is based on an official index of gross value of output of the shipbuilding industry. The prices at which gross value of output is calculated are unspecified, but are probably those of "1926/27." Output is also inflated in the early years by inclusion of civilian types. It excludes naval munitions other than warships, but I do not consider this to be a source of major distortion under peacetime conditions. A case could be made for dropping the prewar years from the naval munitions subindex altogether and simply assuming that the prewar supply of naval munitions grew in line with a weighted average of ground and air munitions. In fact, its inclusion will not make much difference over the period from 1937 to 1940, when shipbuilding output shown in the industry subindex grew 2.3 times, compared to 2.5 times for other munitions types taken together. It is true that the year-to-year movement of the shipbuilding subindex is quite different from that of other subindices, but this is information which seems relevant and interesting.

Of course even in 1940 and after the new subindices are still not perfect. They are based on 16 underlying time series (of which 15 show physical output of munitions, and one shows deflated munitions expenditure). Out of 96 observations required (16 series times the five years from 1940 to 1944, and one half-year, 1945), no less than 33 have been estimated or interpolated. All the estimated observations, however, are anchored in at least one other officially reported observation on either side (intertemporally or simultaneously).

For the war years the best of the new subindices are those covering aircraft, AFV, and guns. Least satisfactory is the ammunition subindex, which is based on a single physical product series. I am unable to judge precisely the reliability of the naval munitions subindex, but I am sure that the evaluation of total munitions output is improved by its inclusion. For the prewar years the only reliably based subindex is the one for guns. Two of the five, the prewar subindices for aircraft and naval munitions, certainly understate output growth before 1940 because of the inclusion of civilian types, the relative importance of which was greater in earlier years.

The most important and ineradicable common defect of the new subindices is their neglect of changing product quality. This is taken into account only when qualitative improvement in weaponry resulted in the expansion of one measured line of output at the expense of another—for example, the growth of medium and heavy tank output relative to that of light tanks. Otherwise it is entirely ignored. Undoubtedly the Soviet fighter-bomber, tank, and gun of 1944 were very different products from those which took the field in 1941. I cannot myself find any way of taking this systematically into account. Nor do I find any solution to this problem in statistical work on the munitions production of other countries in World War II. Thus the new subindices still do not pretend to measure anything more than the volume of output in a relatively crude sense, and represent a lower bound on the true (quality-adjusted) growth of munitions produced.

Still, I believe that for the period from 1937 to 1945 the problem of qualitative change in weaponry is not so great as to destroy the value of a new index of munitions output based on change in the numbers of units produced. It is true that, if we were to try to extend the index further back into the prewar decade, the rapid qualitative improvement then taking place in military technology would begin to represent an uncontrollable problem. This is why I take no year earlier than 1937 for the new subindices' starting point.

The extent of the new subindices' deviation from the old ones is quantified in Table 5. This confirms the utter unreliability of the old ones as guides to the volume of output.

TABLE 5
THE NEW AND OLD SUBINDICES COMPARED
(1944 as percentage of 1940)

	Aircraft	Armored Fighting Vehicles	Guns	Ammunition	Naval Munitions
	239	<i>Istoriia</i> Subindices		310	
		296	206		
		New Subindices			
At 1941 prices	315	1,771	652	902	95
At 1944 prices	323	1,698	611	902	95

Notes and sources: For the *Istoriia* subindices, see Table 1; for the new subindices, see Table 4.

TABLE 6
EXPENDITURE WEIGHTS FOR THE NEW MUNITIONS INDEX, 1941 AND 1944

	1941	1944
Percent of Outlays on Ground and Air Munitions		
Aircraft	35.2%	27.1%
Armored Fighting Vehicles	11.7	12.9
Guns, Ammunition	41.9	43.7
Guns	16.8	17.5
Ammunition	25.1	26.2
Vehicles, Other	11.2	16.3
Total	100.0	100.0
Percent of Total Outlays on Munitions		
Ground and Air Munitions	88.5	93.4
Naval Munitions	11.5	6.6
Total	100.0	100.0

Source: See the Appendix.

TOTAL MUNITIONS OUTPUT—A NEW INDEX

The new subindices can now be combined using appropriate expenditure weights. These weights, shown in Table 6, are derived from officially reported percent shares of the annual munitions budget. The main area of uncertainty is the relative weighting of guns and ammunition. In Table 6, expenditure on guns is divided from expenditure on ammunition in the ratio of 2 to 3 in both 1941 and 1944. This seems consistent both with Soviet evidence and with the available World War II experience of other nations.

Computation proceeds notionally in two stages. First, I combine the subindices of ground and air munitions, incorporating the assumption that the supply of vehicles, tractors, and "other" armament grew at the same rate as the output of other items. Then I combine the resulting index of real output of munitions for the ground and air forces with the naval munitions subindex for the index of total (ground, air, and naval) munitions output, shown in Table 7.

TABLE 7
THE NEW INDEX OF TOTAL SOVIET FINISHED OUTPUT OF MUNITIONS, 1937-1945

At Prices of	1941	1944
Index Numbers		
1937	24	10
1938	36	14
1939	52	21
1940	59	24
1941	100	39
1942	199	73
1943	247	91
1944	274	100
1945 ^a	269	98
1944, Percent of		
1940	466	424
1937	1,147	1,042

^a First six months, at annual rate. Here I assume that the production of naval munitions was evenly spread through the year. This was not the case for ground and air munitions, the year's production of which was heavily concentrated (70 percent) in the first six months; see *Istoriia Vtoroi Mirovoi voiny, 1939-1945* (Moscow, 1980), vol. 11, p. 348. However, the procurement of naval munitions was clearly on a different, and probably rising, trend in 1945.

Source: The five new subindices (Table 4), summed using appropriate expenditure weights (Table 6).

There are two versions of this index, based on the relative munitions prices of 1941 and 1944 respectively. When the base year is 1941, the index shows that Soviet munitions output expanded rapidly in the last prewar years before slowing in 1939/40. The expansion of two and a half times from 1937 to 1940 shown in Table 7 is a little less than that estimated by Abram Bergson.³⁵

At the outbreak of war, Soviet munitions output began to grow with still greater rapidity, even taking into account the early decline in output of naval munitions. The period of fastest growth was 1941/42 when real output doubled. Taking the war as a whole, the year of peak output was 1944. In that year munitions output stood at 4.7 times the 1940 level, and 11.5 times the level already achieved in 1937.

When munitions output is revalued in the prices of 1944, the picture changes only a little. The period of most rapid growth is still 1941/42, and the year of peak output is still 1944. Expansion in 1941/42 is estimated at just under 90 percent; in 1944 peak output still stood at 4.2 times the 1940 level and 10.4 times the level of 1937. Thus the use of

³⁵ Bergson, *Real National Income*, p. 371, gave real Soviet munitions output in 1940 as 2.8 times the level of 1937. Bergson's estimate was based partly on official reports of production (measured in "1926/27 rubles"), partly on reported budgetary appropriations. Some understatement of prewar munitions output growth is likely in Table 7 because of the inclusion of civilian aircraft production, relatively more important than combat types in the earlier years, and the very large weight of aircraft production in prewar rearmament.

“late” prices makes the growth record look a little more modest, but the overall effect is small.

These results are not overly sensitive to substantial variation of assumptions about the relative weights of guns and ammunition. In Table 6 expenditure on guns was divided from expenditure on ammunition in a ratio of 2 to 3 in both 1941 and 1944. Alternatively, spending on guns may be divided from spending on ammunition in the ratios of 3 to 2 or 1 to 4. When the base year is 1941, the only wartime index number to be seriously affected is that for 1942, when the extent of possible bias is plus or minus 3.9 percent. In other years the range of error is less than 1.5 percent. When the base year is 1944, varying assumptions about the relative weights of guns and ammunition have greatest effect again in 1942 (plus or minus 5.9 percent); in other war years the range of error is 2.2 percent or less.

The behavior of Soviet munitions output can be compared with the expansion recorded in some other countries. This is shown in Table 8. According to index numbers shown in the top half of this table, in the United States the production of armaments in 1944 was roughly 6.7 times the 1941 level. British munitions output is known to have peaked in the first quarter of 1944 at 6.5 times the 1939 (fourth-quarter) level; taking 1943 as the calendar year of peak output, the equivalent figure was an expansion factor of 6.0 times. In each case the expansion of munitions output from the outbreak of hostilities to the wartime peak was more rapid and compressed than that of Germany, where the index of munitions output shows peak output in 1944 at 6.3 times the level of 1938. (Table 8 does not, however, take into account any effects arising from Germany's access to weapons produced in Italy or occupied Europe.)

A similar (sevenfold) increase in Soviet munitions output up to the 1944 peak was probably achieved in the period from 1938. This was an interval similar to that required by Germany. The time taken partly reflects the fact that, like Germany, the Soviet Union was an early starter in the interwar arms race and had already built up a relatively high level of output in the late 1930s. By 1941 each country had achieved a similar expansion over 1938. After 1941, however, the munitions indices of the two countries behaved quite differently. Soviet output surged ahead; Germany's delayed burst of effort in munitions production in 1943/44 came too late to reverse the outcome.

The level of munitions output achieved by the warring powers in various years can also be compared. The index numbers shown in the top half of Table 8 can be combined with a rough estimate of relative levels of munitions output of the great powers in 1944. This yields the figures in the bottom half of Table 8, which show each country's munitions output in each year in proportion to that of the United States in 1944. (The table leaves out of account a number of secondary factors:

TABLE 8
THE TOTAL OUTPUT OF MUNITIONS: UNITED STATES, UNITED KINGDOM, USSR,
AND GERMANY, 1937-1944

	United States	United Kingdom	USSR	Germany
Index Numbers, Based on		Jan.-Mar.		Jan.-Feb.
	Mid-1945 ^a	1941 ^a	1944	1942 ^a
1937			10	
1938			14	16
1939		17 ^b	21	20
1940	7 ^c	42 ^c	24	35
1941	15	54	39	35
1942	53	86	73	51
1943	91	102	91	80
1944	100	100	100	100
Percent of United States Munitions Output in 1944				
1937			3	
1938			4	3
1939		3 ^b	6	4
1940	7 ^c	8 ^c	7	8
1941	15	10	12	8
1942	53	17	22	11
1943	91	20	28	17
1944	100	19	31	21

^a For ease of comparison, non-Soviet indices have been recalculated to show 1944 equals 100.

^b Fourth quarter of 1939, at annual rate.

^c Second half of 1940, at annual rate.

Sources: United States: calculated from constant price dollar values in R. Elberton Smith, *The Army and Economic Mobilization* (Washington, DC, 1959), p. 7. United Kingdom: calculated from a quarterly index in Mark Harrison, "A Volume Index of the Total Munitions Output of the United Kingdom, 1939-1944," forthcoming in the *Economic History Review*. USSR: Table 7. Germany: taken from *Die deutsche Industrie im Kriege, 1939-1945* (Berlin, 1954), p. 191. Each country's total (ground, air, and naval) 1944 munitions output is expressed in standard aircraft units, then calculated as a percentage of United States total munitions output in that year. See further the Appendix.

the Canadian contribution to Allied mutual aid; German weapons procurement in Czechoslovakia, France, and Italy; and the Italian and Japanese contributions to Axis strength.)

The table shows that, despite big differences in the scale and pace of prewar rearmament, by 1940 each of the four countries was producing munitions at roughly the same absolute level. This meant that Germany was already being outproduced by three to one (and neither Italy nor even Japan contributed much to offset this disproportion), but of course Germany was not yet actively engaged on land with any of the three future Allies. After 1940, as first Russia then America entered the war, the German disadvantage was compounded and multiplied. In 1942 even the weakened Soviet economy managed to double the effort of German war industries. Thus the table confirms that Germany's failure to win the war in Russia by the end of 1941 was already decisive in its loss of control over the war's outcome.

In 1943/44, as Anglo-American resources were thrown into the balance, the German disadvantage became overwhelming in spite of increasingly frantic efforts. Of the weapons supplied by the three Allies after 1941, two-thirds came from the war industries of the United States alone. One-fifth was supplied by the Soviet Union, and the remainder (one-seventh) came from Great Britain. However, Soviet munitions were also significant out of all proportion to their numerical weight because of their role in the destruction of Germany's fighting strength on land.

Appendix

Tables 3 through 8 rest upon a statistical supplement not reproduced here for reasons of space but available on application to the author. Its contents are briefly summarized below.

A. PRICE DEFLATORS FOR SOVIET MUNITIONS, 1940-1945

For ground and air munitions, a chained Paasche price index of unit procurement costs, 1941-1945 (1940 equals 100) is calculated from the estimated change in prices in each year over the previous year (P_n). The latter is derived from comparing total munitions expenditure of the defense commissariat in period n , in current rubles (E_n), with the ruble saving on NKO munitions expenditures attributed in each year to price reductions over the previous year (S_n). The relationship between these terms is therefore as follows:

$$\begin{aligned} E_n &= \sum p_n q_n \\ S_n &= \sum p_{n-1} q_n - \sum p_n q_n \\ P_n &= \frac{\sum p_n q_n}{\sum p_{n-1} q_n} \\ &= E_n / (E_n + S_n) \end{aligned}$$

For naval munitions an index of procurement costs, 1942-1944 (1941 equals 100), is obtained by chaining together reported figures representing annual percentage price reductions.

B. SOVIET MUNITIONS PRICES, IN RUBLES, 1941-1945

Officially reported ruble prices are listed for nine selected types of aircraft, AFV, and guns in most years, 1941-1945.

C. NEW SUBINDICES OF SOVIET MUNITIONS OUTPUT, 1940-1945

The physical output of different types of aircraft, AFV, and guns is listed as reported, or estimated where official reports are missing, then aggregated and evaluated in index number form on the basis of officially reported ruble prices from B, above. For ammunition, a single physical output series is listed and expressed as an index number.

For naval munitions an index of realized expenditure is derived from official reports and deflated on the basis of estimated trends in procurement costs from A, above.

D. EXTENDING THE NEW SUBINDICES OF SOVIET MUNITIONS OUTPUT BACK FROM 1940 TO 1937

The subindices already derived in C, above, are extended back to 1937. For aircraft, AFV, guns, and ammunition the methodology in each case is consistent with that already applied to the war years. For naval munitions an official index of gross value of output of the shipbuilding industry (1937 equals 100) is employed.

E. ESTIMATING EXPENDITURE WEIGHTS FOR THE NEW MUNITIONS INDEX

The relative weights of the new subindices are established on the basis of officially reported budget data for 1941 and 1944. The relative shares of aircraft, AFV, guns, and ammunition in ground and air forces' expenditure are officially reported or, where missing, estimated on the basis of plausible assumptions and comparative information. The sensitivity of final results to assumptions made at this stage is established.

The share of naval munitions in ruble spending on munitions in 1941 and 1944 is also obtained after considerable further processing of available budget indicators.

F. THE LEVEL OF MUNITIONS OUTPUT IN CROSS-COUNTRY COMPARISON, 1944

Available information on the munitions output of different countries in 1944, expressed in comparable physical units, is presented. Difficulties in using these to establish reliable measures of the relative levels of munitions output in different countries in 1944 are considered, together with alternative solutions and a past precedent.

The method chosen begins with conversion of each country's 1944 aircraft output into internationally standard units of single-engined aircraft equivalents. The latter figure, divided by the share of aircraft in total munitions procurement or supply of each country in 1944, then yields each country's total (ground, air, and naval) 1944 munitions output, expressed in common units of single-engined aircraft equivalents, when each country's ground and naval munitions output is converted to single-engined aircraft equivalents at national prices or costs.