

# A Volume Index of the Total Munitions Output of the United Kingdom, 1939-1944\*

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No official index of the total volume of munitions produced by the UK economy in World War II has ever been published. This is remarkable in itself, and places economic historians of the British war effort in a position inferior to those involved in study of the war production of other major powers.

An index of total UK munitions output was produced in war time, primarily for purposes of current management of the economy. It was compiled in the Ministry of Production, which was set up in February 1942 in order to coordinate war production under conditions of acute generalized shortage in the economy as a whole.<sup>1</sup> The index was designed by E.A.G. (now Professor Sir Austin) Robinson, who became head of the ministry's Programmes Division. Robinson calculated it himself for the first few weeks, and then turned the work of calculation over to his staff.<sup>2</sup>

According to Robinson the index was considered to be rather secret at the time; it was not passed on to the Central Statistical Office then or subsequently, and this is why it was not eventually published in the Statistical digest of the war or in any companion volumes of the United Kingdom civil series of the official History of the Second World War.<sup>3</sup>

## I

The Robinson index was reported weekly and monthly.<sup>4</sup> It covered three main kinds of military goods: army equipment, aircraft, and warships. Indicators were obtained as follows:

- (1) Army equipment was covered by a Ministry of Supply weekly index of finished output which combined guns and gun ammunition, small arms and small arms

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<sup>1</sup> On the Ministry's role see Postan, *British war production*, pp. 248-74; Scott and Hughes, *Administration*, pp. 435-502.

<sup>2</sup> Robinson, letter dated 11 Nov. 1988

<sup>3</sup> Robinson, letter dated 26 Sept. 1988

<sup>4</sup> The index was described in a supplement to the Weekly progress reports entitled "Weekly index of total munitions production" (30 Nov. 1942).

ammunition, and armoured fighting vehicles, valued at fixed prices. The Ministry of Supply index was based on 1939 (September-December) = 100.

- (2) Aircraft were measured by the total structure weight of finished aircraft according to weekly reports of the Ministry of Aircraft Production.
- (3) Most problematic was warship construction for the Admiralty. Vessel completions were too irregular to enter usefully into a weekly index. Instead, total weekly employment on Admiralty work was used, with a lag of 4.5 months; this assumed constant real output per worker and 9 months as the typical period required from initiation to completion of vessels.

These three indicators were weighted by employment shares, setting 1942 (1st quarter) = 100.

The original figures underlying the Robinson index cannot be pinpointed with accuracy. Tests show, however, that the quarterly movement of the monthly index is satisfactorily replicated by combining the Ministry of Supply index of finished output of total warlike stores, published after the war,<sup>5</sup> with total structure weight of finished aircraft, also published after the war,<sup>6</sup> and with series based on wartime estimates of quarterly employment on Admiralty orders with the appropriate lag.<sup>7</sup> Weights for combining army, air force, and naval production were obtained by averaging estimated employment on orders for the three supply departments on 31 December 1941 and 31 March 1942.<sup>8</sup> The resulting percentage shares were as follows:

Ministry of Supply	40.7
Ministry of Aircraft Production	37.0
Admiralty	22.3

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<sup>5</sup> This measure was slightly broader than that available to Robinson. In addition to weapons, ammunition, and armour, it included engineering and allied stores, clothing, and equipment. The broader index was described, and monthly series reported, by Postan, *British war production*, pp. 174-5, 354.

<sup>6</sup> Reported on a quarterly basis in *Statistical digest*, p. 153

<sup>7</sup> This is more complicated than might appear at first. Quarterly employment on Admiralty orders was reported after the war by Inman, *Labour*, p. 5; however, Inman's series was quite different from those available at the time. The latter were not very satisfactory.

<sup>8</sup> See Survey, no. 4 (July 1942) for estimated employment on production for the three supply departments (in '000s):

	<i>31 Dec. 1941</i>	<i>31 March 1942</i>
Ministry of Supply	1,206	1,303
Ministry of Aircraft Production	1,103	1,175
Admiralty	678	695

Employment on Admiralty contracts was not reported before December 1941. Weekly employment in war production, broken down between the three supply departments, first appeared in the WPR only in May 1943, and ran only until March of the following year. Figures based on quarterly censuses of employment went back to Dec. 1941, and from Aug. 1942 attempts were made to estimate employment in the intervening months. These are available from the monthly Surveys. Ironically, however, in view of the high esteem attached to Ministry of Labour statistics, the monthly estimates frequently turned out to understate the apparently rapid underlying change in munitions employment when the results of quarterly censuses became available.

As a result there were no continuous series for the whole war period but rather several discontinuous, overlapping series reflecting successive revisions. This makes it hard to establish what series Robinson's staff used for the index on a continuing basis.

## II

The weekly Robinson index was circulated in the Weekly progress report (hereafter WPR) of the Ministry of Production from November 1942, and a monthly figure was also reported in the Ministry's monthly Survey of United Kingdom production (hereafter Survey).

The weekly and monthly series do not run continuously throughout the war, and in 1943 there were significant unexplained breaks and discrepancies, the reasons for which are no longer clear.<sup>9</sup> At the end of 1943 the weekly index was discontinued on the grounds that too few weekly figures were available for the index to maintain reliability.<sup>10</sup> However, the monthly index continued to appear regularly until the end of the war in Europe; its basis was revised in mid-1944, but the difference resulting was small.

The main features revealed by the Robinson index are shown in table 1. By the first quarter of 1942, a high level of munitions production had already been achieved. However, significant growth was recorded thereafter. The level of output was generally 20-30 per cent higher in the following quarters of 1942. With 1943 there was a jump to a higher level, running 40-50 per cent above the base period. The peak of munitions output came with the first quarter of 1944, the index reaching 165.5 in March. Thereafter a steady decline was observed. The decline was sufficiently gradual, however, for munitions output not to dip below the 1942 (1st quarter) level until the month of Victory in Europe, May 1945.

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<sup>9</sup> Robinson, letter dated 11 Nov. 1988. There may have been a disagreement between the Ministries of Production and Aircraft Production over measurement, but the details are no longer available.

<sup>10</sup> WPR, no. 84 (week ending 4 Dec. 1943).

A feature of the Robinson index which deserves comment is its variability. The weekly index was said to be vulnerable to two influences. One was the tendency of output to be concentrated in the last few days of the month in order to achieve monthly targets. Another was the effect of bank and annual holidays. This could be very marked, and was enough to have a significant impact even on monthly returns.<sup>11</sup>

There were also other reasons for weekly fluctuation. For example, those aircraft were counted in completed output which had passed a flying test by midday on Saturday. Bad weather, or temporary shortages of components, could easily cause a significant dip in the week's production. This kind of fluctuation was easily diagnosed after "a few words on the telephone", and was usually compensated in the following week.<sup>12</sup> But poor winter weather might still give rise to some seasonal variation.<sup>13</sup>

Finally, variation in the Robinson index was significantly smoothed by the use of shipyard employment to measure warship construction.

### III

The Robinson index embodied many compromises. For a start, it was hybrid in concept, measuring a mixture of finished outputs, inputs, and productive activity.

The index was produced under conditions of intense pressure.<sup>14</sup> It was more important to have immediate statistics than perfect ones. And this determined several of the index's features, which were rough and ready from a scholarly standpoint, but serviceable to the war administrator.

Naval production is a case in point. For ground and air munitions the Ministries of Supply and Aircraft Production issued weekly measures of output. But this did not apply where naval munitions were concerned. It was not just that warship completions could not usefully be measured on a weekly basis. Beyond this, "the Admiralty was very much better at producing actual ships than at producing statistics." On the other hand the Ministry of Labour produced regular employment series which were highly regarded. Hence Robinson's use of employment on Admiralty orders to measure naval munitions output.<sup>15</sup> High regard for Ministry of Labour statistics was also a factor in Robinson's decision to weight the index's three component series by employment shares.

The index covered the great bulk of Britain's contribution to Allied munitions supplies. However, there were a few omissions, some of them deliberate—for example,

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<sup>11</sup> See further Devons, *Planning in practice*, pp. 137-40.

<sup>12</sup> Robinson, letters dated 29 Oct., 11 Nov. 1988

<sup>13</sup> Devons, *Planning in practice*, p. 139

<sup>14</sup> Robinson, letters dated 29 Oct., 11 Nov. 1988

<sup>15</sup> Robinson, letter dated 11 Nov. 1988

supplies for special operations in occupied Europe, and for the “Manhattan” project.<sup>16</sup> Military construction, in which airfields figured largely, was another element of war production which the index did not cover.

The index was not seen as more important than the individual items of production on which it was based. An increase in any kind of war production would increase the index, but not all war production would help to win the war. Robinson recalls that:

One could always raise total production by producing more of things that were not wanted. The art of managing production was to concentrate effort on the things that were really needed. If one transferred production from an obsolete weapon to a more modern weapon (e.g. from Stirlings to Lancasters), one lost a number of aircraft produced but gained possibly in military value.<sup>17</sup>

And later on, at a time when resources were constrained and munitions programmes had to be scaled down, “a shortage of landing craft was more serious than some reduction in Bomber Harris’s private war against Germany”.<sup>18</sup>

The index neglected quality as well as composition. For example, lighter aircraft designs would fly faster and with greater manoeuvrability, fuel efficiency, or bomb loads, but would show up in the index as a reduction in completed structure weight.

#### IV

For economic historians the Robinson index has intrinsic interest. But it also suffers from significant defects.

By 1942 the main expansion of war production had already been achieved. The Robinson index does not go back far enough to allow comparison of the years of peak wartime effort with 1939 or with the preceding years of peacetime rearmament. Nor can it be extended back to earlier years on its original basis. While indices of output under the Ministries of Supply and Aircraft Production for 1939-42 on a monthly basis are readily available in published form, the problem is that employment on Admiralty orders (the Robinson index’s third main element) was estimated only from the end of 1940.

To provide a series for real munitions output running continuously from the beginning to the end of the war therefore requires adjustments to the basis of the Robinson index. I made the three following changes.

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<sup>16</sup> Robinson, letter dated 29 Oct. 1988.

<sup>17</sup> Robinson, letter dated 11 Nov. 1988.

<sup>18</sup> Robinson, letter dated 29 Nov. 1988.

First, postwar revisions of the measures of army equipment and aircraft output used by Robinson were incorporated. This involved using the Ministry of Supply index of finished total output of warlike stores, mentioned above, and Postan's index of the total structure weight of completed aircraft "adjusted for man-hours".<sup>19</sup> The latter resulted in a small deflation of growth in the overall index after 1942 because adjusted structure weight of completed aircraft grew less rapidly than total structure weight.

Second, a continuous quarterly series for the volume of warship construction throughout the war was compiled, using crude, unadjusted displacement tonnage of warship completions.<sup>20</sup> This is a much more radical intervention. It makes the overall index significantly more variable because, even on a quarterly calculation, warship completion remained much more variable than shipyard employment. It also makes the overall index generally higher in relation to early 1942, because the first quarter of that year registered relatively poor results (less than half the level of the preceding quarter) in warship construction.

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<sup>19</sup> The labour input and, hence, value added per ton of structure weight varied widely between aircraft types. A four-engined Stirling bomber weighed eleven times as much as a Spitfire, but the hours of work required to manufacture a Stirling were only five times greater. In each period the crude structure weight of different types of aircraft can be weighted by labour input per ton in some base period (here, Jan. 1942) before arriving at a total. When this is done, a more realistic index of the volume of aircraft production is obtained. See Postan, *British war production*, p. 171

<sup>20</sup> This is the result of summing across 13 warship classes listed in *Statistical digest*, pp. 133-4. In theory displacement tonnage could be adjusted by value added per ton for each class of vessel in some base period, similarly to the adjustment of aircraft structure weight. However, I have no information on which to base such an adjustment, nor do I think it necessarily justified. This kind of correction would be desirable given a combination of two circumstances. One is that the composition of naval construction must change significantly over the period. This was indeed the case. (For example, in 1942 battleships, aircraft carriers, and cruisers accounted for nearly one-quarter of completed warship tonnage, and landing craft accounted for up to another quarter. In 1944 the share of landing craft had risen to nearly one-half, while that of capital ships had fallen to one-seventh.)

At the same time, however, there must be grounds to suppose that there were significant differences in value added per ton of the different classes. Here I do not know what assumption to make. In aircraft production smaller aircraft embodied more value added per ton, because they embodied relatively more motive power, instrumentation, and combat equipment. This was probably also true of the smaller warship classes. However, this must have been offset by major economies of scale in the production of small vessels and landing craft compared to the one-off character of building battleships and aircraft carriers. Therefore, the displacement tonnage of warship completions was not adjusted, since, however distorted, it represents an improvement on shipyard employment for my purposes.

Third, the three subindices were reweighted by employment shares of the three specialized branches drawn from periods both earlier and later than the first quarter of 1942. The new index was calculated in two variants, reflecting “early” and “late” employment weights. The two base periods are the first quarters of 1941 and 1944. The first quarter of 1941 was used because it was the earliest for which average quarterly employment under the three supply departments could be calculated. The first quarter of 1944 was used because it witnessed the peak of war production, whatever base period is chosen.

The new index is therefore no longer calculated in terms of Robinson’s base period, the first quarter of 1942, which was originally selected for circumstantial reasons reflecting the necessities of the time. The beginning of 1942 is not a particularly useful base period, being neither “early” nor “late” in the war; it was also untypical by reason of the abnormally low level of warship completion.

The percentage weights used for the revised index are as follows:<sup>21</sup>

	<i>1941 (1st qtr)</i>	<i>1944 (1st qtr)</i>
Ministry of Supply	37.0	36.5
Ministry of Aircraft Production	39.5	43.1
Admiralty	23.4	20.4

These percentages differ a little from Robinson’s original weights (mainly by raising the significance of aircraft production at the expense of army equipment), but not by enough to make any substantial difference.

Revised on this basis, the new index is less hybrid in character than Robinson’s. It is more consistently a measure of finished output. However, two out of the three component subindices measure finished output by the weight of embodied inputs.

The index’s most important and ineradicable remaining defect is neglect of changing product quality. Undoubtedly the British weapons sent into action on D-Day in 1944

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<sup>21</sup> Inman, *Labour*, p. 5, gives postwar estimates of employment on production for the three supply departments (’000s) at the start and finish of the two new base periods:

	<i>31 Dec.</i>	<i>31 Mar.</i>	<i>31 Dec.</i>	<i>31 Mar.</i>
	<i>1940</i>	<i>1941</i>	<i>1943</i>	<i>1944</i>
Ministry of Supply	937.3	1,012.7	1,459.5	1,422.2
Ministry of Aircraft Production	997.8	1,092.6	1,711.6	1,687.1
Admiralty	619.7	619.9	806.5	806.1

For lack of any alternative, I continue to rely on employment shares. These do not even reflect total labour inputs, but only numbers employed in the last, most specialized stages of fabrication of materials and components and their assembly. There is an implicit assumption of uniform gross output per worker in the different specialized branches in the base period. It would be useful to know the effect of using weights based on relative total factor costs or expenditure shares instead of on relative employment at the final stage. But the necessary information on the cost and composition of Britain’s spending on military equipment in any of the war years has never been published.

were very different products from those which had gone with the expeditionary force to France in 1939. I cannot 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 index will not pretend to measure anything more than the volume of output in a relatively crude sense, and represents a lower bound on the true (quality adjusted) growth of munitions produced.

## V

The new index covers the years 1939-44 on a quarterly basis. Its quarterly periodization is made necessary by the measure of warship construction. It runs back to the last quarter of 1939, but there are still gaps. These are attributable to breaks in the Ministry of Supply index; they mean that there is no measure of total munitions output under prewar rearmament, in the first half of 1940, or after 1944.

The revised index is presented in table 2. When "early" (1941, 1st quarter) weights are used, the values of the index differ from Robinson's index figures mainly by being more variable; this reflects the influence of the new measure of naval output. The revised measures of aircraft and warship construction induce offsetting changes in the height of the index relative to Robinson's base period. As a result, the height of the peak of munitions output in 1944 (1st quarter) is virtually unaltered at 1.5-1.6 times the level of 1942 (1st quarter) output.

The revised index shows clearly that the main expansion of munitions output came before 1942. If we compare peak munitions output not with 1942 but with 1939, we find that output reached 4.2 times the level achieved in the first quarter of the war by 1942 (1st quarter), and 6.5 times this level at the 1944 (1st quarter) peak.

When rebased using "late" (1944, 1st quarter) weights, the index's behaviour does not change significantly. At the peak, which still falls in 1944 (1st quarter), war production was 1.6 times the level of 1942 (1st quarter) and again 6.5 times the level of 1939 (4th quarter). In physical terms the 1944 (1st quarter) peak represented a weekly U.K. output of more than 500 aircraft, 3,000 tons of aircraft bombs, 450 guns, 1.5 million shells and mines, 700 armoured fighting vehicles, 33,000 small arms, 8 warships, and nearly 30 landing craft.<sup>22</sup> These results cannot fail to remind us of the degree to which World War II became a war of production.

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<sup>22</sup> Statistical digest, pp. 133-4, 140-1, 144-6, 148, 152.

*Table 1. Total munitions output of the U.K., 1942-1945 (monthly and quarterly series): the Robinson index (1942, first quarter = 100)*

<i>Year and quarter</i>	<i>Weekly index, average<sup>a</sup></i>	<i>Monthly index<sup>b</sup></i>	
		<i>Series A</i>	<i>Series B</i>
1942			
April	...	...	...
May	...	...	...
June	123.0	...	...
2nd qtr	...	...	...
July	116.5	...	...
Aug.	115.0	...	...
Sept.	129.5	131.2	...
3rd qtr	120.3	...	...
Oct.	135.2	135.2	...
Nov.	125.8	c. 130	...
Dec.	127.0	127.0	...
4th qtr	129.3	130.7	...
1943			
Jan.	130.8	131.0	...
Feb.	144.8	145.0	...
March	146.0	146.0	...
1st qtr	140.5	140.7	...
April	144.5	146.0 <sup>c</sup>	...
May	142.2	151.1	...
June	133.0	...	...
2nd qtr	139.9	...	...
July	132.0	...	...
Aug.	118.3	...	...
Sept.	137.0	...	...
3rd qtr	129.1	...	...
Oct.	134.6	c. 150	...
Nov.	131.7 <sup>c</sup>	151.0	...
Dec.	...	142.1	...
4th qtr	...	147.7	...
1944			
Jan.	...	152.2	150.0
Feb.	...	155.1	
March	...	165.5	161.2
1st qtr	...	157.6	

<i>Year and quarter</i>	<i>Weekly index, average<sup>a</sup></i>	<i>Monthly index<sup>b</sup></i>	
		<i>Series A</i>	<i>Series B</i>
April	...	151.9	149.3
May	...	156.3	
June	...	153.6	147.0
2nd qtr	...	153.9	
July	...	138.9	133.0
Aug.	...	...	133.7
Sept.	...	...	140.7
3rd qtr	...	...	135.8
Oct.	...	...	142.4
Nov.	...	...	138.3
Dec.	...	...	115.8
4th qtr	...	...	132.2
1945			
Jan.	...	...	108.7
Feb.	...	...	127.9
March	...	...	126.6
1st qtr	...	...	121.0
April	...	...	105.4
May	...	...	95.4
June	...	...	95.8
2nd qtr	...	...	98.8

## Notes:

- a. Monthly and quarterly averages of the weekly index are calculated from series found in "Weekly index of total munitions production" (30 Nov. 1942), and in subsequent issues of the Weekly progress report, up to WPR, no. 84 (10 Dec. 1943) when the demise of the weekly index was announced.
- b. The monthly index is reported from the monthly Survey of United Kingdom production. Some adjustment was made to the basis of the monthly index in mid-1944, with corrections back to the beginning of the year. For convenience I refer to the monthly index before and after the mid-1944 correction as "Series A" and "Series B". The quarterly index is calculated from the weekly data.
- c. First three weeks only.

*Table 2. Total munitions output of the UK, 1939-1944 (quarterly series): the Robinson index revised*

Year and quarter	The Robinson index (Series A) <sup>a</sup>	The revised index	
		1941 (1st qtr) = 100 <sup>b</sup>	1944 (1st qtr) = 100 <sup>b</sup>
1939 1st	...	...	...
2nd	...	...	...
3rd	...	...	...
4th	...	37.1	15.4
1940 1st	...	...	...
2nd	...	...	...
3rd	...	86.4	36.1
4th	...	92.4	40.1
1941 1st	...	100.0	42.8
2nd	...	108.2	45.7
3rd	...	113.9	46.9
4th	...	141.2	60.4
1942 1st	100.0	155.1	62.4
2nd	...	198.5	82.6
3rd	...	201.1	82.8
4th	130.7	210.3	85.6
1943 1st	140.7	219.1	89.1
2nd	...	228.5	94.2
3rd	...	217.5	90.0
4th	147.7	233.0	97.1
1944 1st	157.6	241.8	100.0
2nd	153.9	234.7	97.6
3rd	...	203.0	83.1
4th	...	199.1	81.9
		As per cent of 1942 (1st qtr):	
1944 1st	157.6	155.9	160.2
		As per cent of 1939 (4(h qtr):	
1942 1st	...	418	406
1944 1st	...	651	650

Sources:

- a. Table 1.
- b. See text for detail.

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