

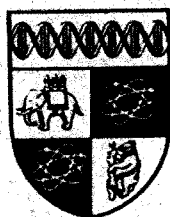
A VOLUME INDEX OF THE TOTAL MUNITIONS OUTPUT
OF THE UNITED KINGDOM, 1939-1944

by

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This paper is circulated for discussion purposes only and its contents should be considered preliminary.

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Abstract

The paper presents a previously unpublished index of the total British output of munitions, 1942-5. The index was produced in the Ministry of Production's Programmes Division under E.A.G. (now Professor Sir Austin) Robinson in both weekly and monthly versions. The Robinson index was used mainly for purposes of short run management of munitions production and manpower budgets. For today's more long run historical purposes the index can be revised and extended back to 1939 on a quarterly basis. The revised index shows a fourfold increase in British munitions output in the first 18 months of the war; by the 1944 peak, munitions output was running at more than six times the October-December 1939 rate. The level and dynamic of British munitions output estimated in this way can also be compared with the performance of similar indicators of munitions output in World War II in other countries.

Acknowledgements

I am grateful to the following: Professor Sir Austin Robinson, for permission to refer to his papers held in the Churchill Archives Centre, Churchill College, Cambridge, for permission to make use of his personal correspondence, and for his kindness in making freely available to me his valuable recollections and advice; the staff of the Churchill Archives Centre, for their help in providing access to the Robinson papers; the Central Office of Information, for permission to make use of Crown Copyright material; Dr Peter Howlett (Stirling) and Professor Alan Milward (LSE), for advice at an early stage; the University of Warwick, for the leave of absence which made this work possible.

A volume index of the total munitions output of the United
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I

Introduction

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 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 early in 1942 in order to coordinate war production as a whole. (The first Minister was Lord Beaverbrook, but he was succeeded after a few days by Oliver Lyttelton, who remained Minister until the end of the war.) This ministry's responsibilities came to include, 'in the absence of any alternative, some of the more general economic and statistical functions which more properly belonged to any central coordinating body in the field of

munitions production'.¹ Among them was calculation of an index of total munitions output.

The index was designed by E.A.G. (now Professor Sir Austin) Robinson,² who became head of the ministry's Programmes Division. Robinson compiled it himself for the first few weeks, then turned the work of calculation over to his staff.³

The index was so secret at the time that it was never passed on to the Central Statistical Office, and this is why it was not published later 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*.⁴

II

The Robinson index

The Robinson index of total munitions output was, to begin with, a weekly series. It covered three main kinds of military goods: aircraft, army equipment and warships.

Indicators for the three groups were obtained as follows:

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- 1 Robinson, 'The overall allocation', 44-5.
 - 2 Before the war Robinson was a Fellow of Sidney Sussex College, Cambridge and Lecturer in Economics at the University. He joined the Central Economic Information Service and the Economic Section of the War Cabinet Secretariat in 1939. In 1942 he was appointed Economic Adviser and head of the Programmes Division (formerly Planning and Programmes Department) of the Ministry of Production, and he served there until 1945.
 - 3 Robinson, letter dated 11 November 1988.
 - 4 Robinson, letter dated 26 September 1988.

- a Army equipment was covered by a Ministry of Supply weekly index which combined guns and gun ammunition, small arms and small arms ammunition, and armoured fighting vehicles, at fixed prices. The Ministry of Supply index was based on 1939 (September-December) = 100.
- b Aircraft were measured by the total structure weight of completed aircraft according to weekly reports of the Ministry of Aircraft Production.
- c 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 four and a half 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 index clearly covered the great bulk of Britain's contribution to the total munitions output of the Allies. There were a few omissions, some of them deliberate. For example, Robinson was told by Lyttelton:

... to lay on the production of certain things wanted by our secret service people for very secret operations

on the continent of Europe ... I laid them on privately with George Turner in the Ministry of Supply and never heard any more about them. But statistically that amounted to nothing. Again, I knew nothing about the Bomb and our contribution to it at Los Alamos. Again, I suspect that statistically it is nothing to worry about.^a

Military construction was another thing which the index did not try to count. For example, the building of airfields figured largely in the British contribution to mutual aid of the United States forces in Britain, along with food, clothing and so on.

The weekly Robinson index was circulated in the *Weekly Progress Report* (hereafter *WPR*) of the Ministry of Production from November 1942. The index was also produced on a monthly basis, and was circulated by the Ministry of Production in this form in its monthly *Survey of United Kingdom Production* (hereafter *Survey*).

The weekly and monthly series do not run continuously throughout the war, and they reveal some discrepancies. There was an unexplained break in the monthly series from June to September 1943 when the monthly *Surveys* reported the sign of the change in the index but not its exact level. The monthly index was next reported with an approximate value for October 1943 and an exact value for November. These

^a Robinson, letter dated 29 October 1988.

showed that something was now clearly wrong with the weekly index in the *WPR*, the monthly average of which was now running up to twenty points below the *Survey* level of 150.

Reasons for the break and the discrepancy are no longer clear. There may have been a disagreement between the Ministries of Production and Aircraft Production over measurement, but the details are no longer available for recall.⁶

At this point the weekly index was discontinued on the grounds that too few weekly figures were available for the index to maintain reliability.⁷ 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 of munitions production revealed by the Robinson index are as follows. 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

6 Robinson, letter dated 11 November 1988.

7 *WPR* no. 84 (week ending 4 December 1943).

sufficiently gradual, however, that munitions output did not dip below the 1942 (1st quarter) level until the month of Victory in Europe, May 1945.

A feature of the Robinson index which deserves comment is its variability. The weekly index was said to be vulnerable to two factors. One was the tendency of output to be concentrated in the last few days of the month in order to achieve monthly programmes. There were quarterly and annual programmes, too, but their influence on the bunching of production operations was of less concern. Another source of variation was the effect of Bank and annual holidays. This could be very marked, and was enough to have a significant impact on monthly returns. In the first week of August 1943, for example, output stood at 85 compared with 120 the week before and 144 in the first week of September.

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.⁸ It was unlikely to have much effect on monthly or (still less) quarterly returns.

⁸ Robinson, letters dated 29 October and 11 November 1988.

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

III

Uses of the Robinson index

The index was produced under conditions of intense pressure. Walter Layton, chief adviser to the Minister of Production,

... insisted, on the basis of his first war experience, that we must get the statistics out almost instantaneously. The weekly report was on the desk of the Minister, the Permanent Secretary, and everybody else concerned in our ministry as well as on those of [other] people concerned by 9.00 a.m. on Monday morning, complete down to midday of the previous Saturday. It meant that certain members of my staff had to work very hard indeed over the weekend. But it meant also that any index had to be capable of being calculated in a few minutes and did not involve enormous numbers of calculations with detailed weights.*

The weekly report had to be instantaneous. The monthly report could be written a little more at our leisure.

9 Robinson, letter dated 29 October 1988.

But in that case also we had to be sure that the monthly data would be quickly available so that our monthly report came out very soon indeed after the end of the month.¹⁰

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 scholastic standpoint, but serviceable to the war administrator. Naval production is a case in point. For ground and air munitions production the Ministries of Supply and Aircraft Production produced serviceable weekly measures. But this did not apply where naval munitions were concerned. It was not just the intrinsic difficulty of a weekly (or even monthly) measure of warship construction. There was also the problem that '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 reliance on shipyard employment on Admiralty orders to capture the Admiralty contribution to total munitions output.¹¹

High regard for Ministry of Labour estimates of employment on production for the three supply departments also helped to determine Robinson's choice of employment shares as means of weighting the index's three component series.

10 Robinson, letter dated 11 November 1988.

11 Robinson, letter dated 11 November, 1988.

Why were ready statistics so urgent? Urgency reflected their administrative uses. The Robinson index was useful as a summary measure of progress in war production, and this was something of primary interest to Robinson's outfit. For a chief role of the Programmes Division was to act as progress chaser and trouble shooter for the munitions industries. At the same time, the index was not 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.¹²

And later on in the war, 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.¹³

12 Robinson, letter dated 11 November 1988.

13 Robinson, letter dated 29 November 1988.

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.

The role of the weekly report, therefore,

... was not to provide the data from which we composed an index of production. It was to provide the weekly information about actual production. We scrutinised it very carefully each Monday morning. If something had gone wrong we immediately enquired from the ministry concerned what had gone wrong. We got our regional department on to it if the problem was manpower. We got the materials people on to it if the problem was materials. But the essential thing was to correct difficulties just as quickly as was humanly possible. We had indeed a small department of experts whom we could send in if bombing had upset production of any component and we would not hesitate to send them in with very considerable powers.¹⁴

Perhaps the practical significance of the Robinson index within the Ministry of Production itself was not so great. But there was one other major role for an index of total munitions output to play, and this brought in much broader issues of national economic coordination. The wider

¹⁴ Robinson, letter dated 11 November 1988.

stage was created by manpower policy. In war time manpower budgets were drawn up every six months or so.¹⁵ At this time the expected change in the nation's available labour resources had to be balanced with the change in forecast demand. On the demand side, a key element was the plans of the munitions producing ministries for increased output, with which would be associated increased labour requirements. These had to be summed and set against expected or necessary changes in civilian requirements. When draft munitions programmes were scaled down (as they invariably had to be), the associated (scaled down) manpower intake had to be feasible. The Robinson index helped to check the expected demands of munitions production against resources available and to balance the economy.¹⁶

IV

The Robinson index - its uses today

For economic historians the Robinson index has intrinsic interest. It supplies an essential summary measure of the British productive effort at the height of the war, and it shows the path of munitions output through time in unique detail. It casts new light on the statistical basis of central economic decisions and policies in war time. It also offers the possibility of comparison with other

15 See further Robinson, 'The overall allocation', 47-54.

16 Robinson, letter dated 29 November 1988.

countries' measures of war production. In recognition of its possible uses for historians today, the Robinson index is published in Appendices A (weekly series, 1942-3) and B (monthly and quarterly series, 1942-5) below.

At the same time, from today's vantage point the Robinson index suffers from a central defect. By 1942 the main achievements in expanding the volume of war production had already been registered. 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. Designed as a guide to immediate action, it does not raise perspectives on the long view. Moreover, it cannot easily be extended back to earlier years. It is true that indices of output under the Ministries of Supply and Aircraft Production for 1939-42 are available on a monthly basis in published form. However, employment on Admiralty orders, which is the Robinson index's third main element, was estimated only from the end of 1940.

To provide a series for real munitions production running continuously from beginning to end of the war therefore requires revision of the Robinson index. Revision can involve both those steps which are necessary and those which are merely desirable. A necessary step is compilation of a continuous series for the volume of naval construction. Having done that which is necessary, we can also undertake

some improvements. First, we can improve on the measures of production of army equipment and aircraft which Robinson used. Second, we can investigate the results of rebasing the index.

Rebasing the index means trying out other weights for the index's main components, using some other measure of value or some other base period. (The three component subindices, however, are not revalued when the weights are changed.)

Robinson originally used employment shares to weight the index, rather than some financial measure of relative values. It would be useful to know the effect of using weights based on relative prices or on expenditure shares instead of on relative employment. But the necessary information on the composition of Britain's military spending in any of the war years has never been published. Therefore, we must continue to rely on employment shares, which carry with them the assumption of uniform value added per worker in the different branches in the base period. Subject to this limiting assumption, we can discover the effects of reweighting the index by 'early' and 'late' employment shares.

The result is a revised index covering the years 1939-44 on a quarterly basis. Its quarterly periodisation is forced by the available measures of warship construction and the discontinuities of vessel completion which have already

been mentioned. Anyway, a quarterly index is better than weekly or monthly figures for providing a long view. For those primarily concerned with very short run management the original weekly and monthly Robinson indices are still available.

The revised index is predicated upon statistical uses and resources which were inappropriate or unavailable in war time. Then, Robinson writes,

... the essential thing was to get the information into the hands of people who could deal with it just as quickly as was humanly possible. Thus I have to ask myself, wherever you suggest an alternative, whether that alternative really existed on a Saturday morning in wartime. If it did not, then we had to use whatever alternative was in fact available.¹⁷

v

Decomposing the Robinson index

In order to improve upon the Robinson index, we must first take it apart and establish how it works. This is done below in Table 1. The first two columns of the Table show quarterly averages of the index (Series A and B) as reported in the monthly *Surveys*. The third column shows my best attempt to simulate it.

17 Robinson, letter dated 11 November 1988.

Table 1. *Munitions output of the UK (1942-5, quarterly series): the Robinson index simulated*

Year and quarter	The Robinson (monthly) index: ^a		The Robinson index simulated ^b
	Series A	Series B	
1942:			
1st	100.0	100.0	100.0
2nd			115.2
3rd	(120.3) ^c		122.7
4th	130.7		133.3
1943:			
1st	140.7		140.5
2nd	(139.9) ^c		144.2
3rd	(129.1) ^c		139.2
4th	147.7		146.2
1944:			
1st	157.6		155.6
2nd	153.9		150.7
3rd		135.8	139.1
4th		132.2	134.3

Notes and sources:

- a See Appendix B.
- b For the Ministry of Supply index of total completed warlike stores and for the total crude structure weight of completed aircraft, see Appendix C. For end-of-quarter employment on Admiralty orders see Appendix D, Table D-1 ('adjusted' series, used here with a 4.5 month lag). For weights, see text.
- c Calculated from the weekly index (Appendix A).

My simulation combines the following elements, documented in Appendices C (measures of production) and D (estimated employment on Admiralty orders). Army production is measured by the Ministry of Supply monthly index of total completed output of warlike stores. This measure is a little broader than that used originally by Robinson; in addition to armoured fighting vehicles, guns, small arms, and their respective ammunition, it includes engineering and allied stores, clothing and equipment. Air force production is measured by the total crude structure weight of completed aircraft, and this is the same as Robinson's measure.

Naval production is a more difficult problem. As explained above, Robinson regarded shipyard completions as too irregular to enter usefully into a weekly index. Instead, employment on Admiralty work was used, with a lag of four and a half months. Ironically, however, in view of the high esteem attached to Ministry of Labour statistics, employment estimates were often found to be substantially in error and were frequently revised, so that it is hard to establish what series Robinson's staff used on a continuing basis. I try to reproduce the kind of continuous series which I think would have seemed plausible to them at the time, using sources and methods explained in Appendix D.

Employment weights based on 1942 (1st quarter) for combining the three indicators of army, air force and naval production were obtained by averaging employment on orders

for the three supply departments on 31 December 1941 and 31 March 1942. Here I assume that Robinson's weights, having once been calculated on the basis of the employment estimates for 1942 (1st quarter) which were current in mid-1942, were never subsequently revised in light of later estimates of 1942 (1st quarter) employment. The resulting employment shares, per cent, were as follows:¹⁸

<i>Ministry of Supply</i>	40.7
<i>Ministry of Aircraft Production</i>	37.0
<i>Admiralty</i>	22.3

The simulated index shown in Table 1 turned out to be a close copy of the original, and satisfied me that I had approximated to Robinson's original method. It also served, incidentally, to confirm that the weekly Robinson index was understating munitions production in the second and third quarters of 1943; and (a weaker result) that there was a small upward bias in Robinson's monthly Series A in early 1944, prior to its revision (Series B).

¹⁸ See Survey no. 4 (July 1942) for estimated employment on production for the three supply departments (in thousands):

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

VI

Variations on the Robinson theme

How sensitively does the Robinson index respond to improvement? This is investigated in Table 2. Here are presented separately the effects of four alterations. First, 1942 (1st quarter) percentage employment weights are adjusted to take into account revised estimates published in the postwar years:¹⁹

<i>Ministry of Supply</i>	42.6
<i>Ministry of Aircraft Production</i>	37.9
<i>Admiralty</i>	19.5

This revision is shown to have almost no effect.

Second to be considered is replacement of the total structure weight of completed aircraft by structure weight adjusted for man-hours. 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 a Spitfire, but the man-hours required for to manufacture a Stirling were only five times greater. In each

¹⁹ See Inman, *Labour*, 5 for revised estimates of employment on production for the three supply departments (in thousands):

	31 Dec 1941	31 Mar 1942
<i>Ministry of Supply</i>	1 433.9	1 540.0
<i>Ministry of Aircraft Production</i>	1 286.7	1 364.2
<i>Admiralty</i>	676.4	685.8

Table 2. *Munitions output of the UK (1942-5, quarterly series): variations on the Robinson index*

Year and quarter	The Robinson index simulated:				
	As in Table 1	With revised 1942 (1st qtr) weights ^a	With adjusted structure wt of aircraft ^b	With revised employment on Admiralty orders ^c	With tonnage of warships completed ^d
1942:					
1st	100.0	100.0	100.0	100.0	100.0
2nd	115.2	115.3	114.7	114.3	143.3
3rd	122.7	122.8	120.9	120.1	141.8
4th	133.3	133.4	131.3	128.3	143.0
1943:					
1st	140.5	140.5	137.5	135.5	149.9
2nd	144.2	144.1	140.3	138.9	164.1
3rd	139.2	139.0	135.7	133.9	158.0
4th	146.2	146.8	141.8	140.9	174.3
1944:					
1st	155.6	155.5	150.6	150.3	177.7
2nd	150.7	150.5	145.9	145.4	175.3
3rd	139.1	138.9	134.8	134.2	144.9
4th	134.3	134.1	130.1	129.4	143.7

Notes and sources:

- a For weights, see text.
- b For the Ministry of Aircraft Production index of total structure weight of completed aircraft, adjusted for man-hours, see Appendix C.
- c For postwar estimates of employment on Admiralty orders at the end of each quarter (incorporated here with a lag of 1.5 quarters), see Inman, *Labour*, 5.
- d For total displacement tonnage of completed warships, see Appendix C.

period the crude structure weight of different types of aircraft can be weighted by labour input per ton in some base period (here, January 1942) before arriving at a total. When this is done, a more realistic index of the volume of aircraft production is obtained.²⁰ When the index of adjusted structure weight is substituted into the simulated Robinson index, the result is a small deflation of the growth of total munitions output after the base period.

Third, Robinson's proxy for warship construction (lagged employment on Admiralty contracts) can be revised. Substituting the revised employment series published after the war amounts to relatively minor surgery.²¹ It rises by rather less than the series which I believe Robinson's staff to have used (Appendix D). Consequently, the Robinson index is again deflated, by an amount similar to the deflation resulting from use of adjusted structure weight of completed aircraft.

Fourth, a direct measure of the volume of warship construction can be substituted for Robinson's proxy. This involves more radical intervention. I use the crude, unadjusted displacement tonnage of warship completions, which can be calculated from available sources on a quarterly basis (for details, see Appendix C). I have no information on which to base an adjustment of displacement tonnage by value added per ton in any base period, similar

20 Postan, *British war production*, 171.

21 Inman, *Labour*, 5.

to that undertaken for aircraft production. Nor do I think it necessarily justified.

Such a 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. The latter 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, I do not make any adjustment to the displacement tonnage of warship completions, but regard it, however distorted, as an improvement on shipyard employment for our purpose.

When the new data are substituted into the simulated Robinson index, a major change is visible. Like the old index, the new one shows substantial growth peaking in the first quarter of 1944. But it is much more variable because, even on a quarterly calculation, warship completion remained much more variable than shipyard employment. It is also generally higher in relation to the base period, because the first quarter of 1942 registered relatively poor results (less than half the level of the preceding quarter) in warship construction. This factor alone is sufficient to explain the difference in the peak value (178 compared to 156 in the original simulation).

The most important and ineradicable remaining defect of the new data is their neglect of changing product quality. Undoubtedly the British weapons sent into action on D-Day in 1944 were very different products from those which had gone with the expeditionary force to France in 1939. 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 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.

VII

The revised index

All of the 'improvements' tested above in relation to the Robinson simulation can be incorporated into a revised index of the volume of UK munitions output. The revised index is presented in Table 3. With the help of our measure of naval output it now runs back to the last quarter of 1939, but there are still gaps. These are attributable to breaks in the Ministry of Supply index of production for the army; they mean that there is no measure of total munitions output under prewar rearmament, in the first half of 1940, or after 1944.

The new index is 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 is used because it is the earliest for which average quarterly employment under the three supply departments can be calculated. The first quarter of 1944 is used because it witnessed the peak of war production, whatever base period is chosen. The index is 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 naval construction reported.

Table 3. *Munitions output of the UK (1939-44, quarterly series): the Robinson index revised*

Year/qtr	The Robinson index (Series A) ^a	The revised index:	
		1941 (1st qtr) = 100 ^b	1944 (1st qtr) = 100 ^b
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
<i>As per cent of 1942 (1st qtr):</i>			
1944 1st	157.6	155.9	160.2
<i>As per cent of 1939 (4th qtr):</i>			
1942 1st		418	406
1944 1st		651	650

Notes and sources: See next page.

Following page 21

Notes and sources for Table 3:

- a** See Table 1.
- b** For the Ministry of Supply index of total completed warlike stores, for total structure weight of completed aircraft adjusted for man-hours, and for total displacement tonnage of completed warships, see Appendix C. For weights, see text.

The percentage weights used for the revised index are as follows:²²

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

When based on 'early', 1941 (1st quarter) weights, the index performs as might be expected in light of our preliminary investigation. The revised index's story differs from that of the Robinson index mainly by being more variable, the reason being the use of a direct measure of naval output. The revised measures of aircraft and warship construction also induce offsetting changes in the height of the index relative to the 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 1942 (1st quarter) output.

²² See Inman, *Labour*, 5 for postwar estimates of employment on production for the three supply departments (in thousands) at the start and finish of the two new base periods:

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

The revised index shows clearly that the main expansion of munitions output was recorded before 1942. Let us compare peak munitions output not with 1942 but with 1939. Munitions 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 on '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).

The sixfold expansion of British munitions output from the outbreak of war to the war effort's peak can be compared with the expansion recorded in some other countries. In the United States the pace of expansion was still faster than in the United Kingdom, and the production of armaments in 1944 was roughly 6.7 times the 1941 level.²³ In both the British and the American cases, however, the expansion of munitions output from the outbreak of hostilities to the wartime peak was more rapid and compressed than that of either the German adversary or the Soviet ally. An index of Soviet munitions output shows the peak in 1944 at 6.7 times the level of 1938.²⁴ A similar increase in German munitions output up to the 1944 peak (6.3 times) was probably achieved in the

23 Smith, *Army*, 5.

24 Harrison, 'Volume', Table 6.

period from 1938.²⁵ The slower pace of Soviet and German expansion partly reflects the fact that these two were early starters in the interwar arms race and had already achieved a relatively high level of output in the late 1930s.

The level of munitions output achieved by the warring powers in various years can also be compared.²⁶ The high initial level of Soviet war production, and the rapid growth of British and American output, meant that by 1941 each of the three Allies was producing munitions at roughly the same absolute level as Germany. Their munitions output was also expanding rapidly at a time when German munitions output was growing at a relatively leisurely pace. After 1941, therefore, the German disadvantage was compounded and multiplied. In 1942, even the weakened Soviet economy managed to outproduce Germany's war industries. In 1943-4, as Anglo-American resources were increasingly engaged with the adversary, the German disadvantage became overwhelming in spite of a belated burst of effort in economic mobilisation.

25 *Die deutsche Industrie*, 191.

26 The comparison depends on rough estimates of the 1944 munitions output of the other powers expressed as percentages of the 1944 munitions output of the United States by Goldsmith, 'Power of victory', 71, as follows:

United States	100
United Kingdom	about 25
USSR	over 35
Germany	about 40

For supporting detail see Harrison, 'Volume', Table 7.

A distinctive feature of the British record is that the British munitions effort reached a ceiling relatively early in the war. During most of 1942 British munitions industries were already within 15-18 per cent of peak output. By contrast Soviet munitions output still fell below the 1944 peak by more than one quarter, and the munitions output of both the United States and Germany by almost one half. The failure to raise output much further restricted the British contribution to Allied munitions in the decisive phases of the war. Of the weapons supplied by the three Allies after 1941, three fifths came from the war industries of the United States alone and nearly a quarter was supplied by the Soviet Union.

The British share amounted to no more than one sixth. But this must be considered alongside other British contributions which were of growing importance in 1943-4, especially in staging, servicing and launching the vast concentration of Allied D-Day invasion forces, and in providing the British military contingent.

Appendix A. *Munitions output of the UK: The weekly Robinson index, 1942-3*Table A-1. *The Robinson index, 1942-3 (weekly series)*

Week ending	Weekly index	Week ending	Weekly index
1942 (first quarter) = 100			
1942:			
6 Jun	122	3 Oct	138
13 Jun	119	10 Oct	124
20 Jun	130	17 Oct	132
27 Jun	121	24 Oct	132
		31 Oct	150
4 Jul	119		
11 Jul	114	7 Nov	117
18 Jul	111	14 Nov	120
25 Jul	122	21 Nov	136
		28 Nov	130
1 Aug	123		
8 Aug	90	5 Dec	133
15 Aug	118	12 Dec	133
22 Aug	116	19 Dec	129
29 Aug	128	26 Dec	113
5 Sep	126		
12 Sep	128		
19 Sep	133		
26 Sep	131		

(continued)

Table A-1 (continued). *The Robinson index, 1942-3 (weekly series)*

Week ending	Weekly index	Week ending	Weekly index
1942 (first quarter) = 100			
1943:			
2 Jan	119	3 Jul	153
9 Jan	110	10 Jul	123
16 Jan	134	17 Jul	133
23 Jan	136	24 Jul	131
30 Jan	155	31 Jul	120
6 Feb	140	7 Aug	85
13 Feb	140	14 Aug	114
20 Feb	144	21 Aug	134
27 Feb	155	28 Aug	140
6 Mar	146	4 Sep	144
13 Mar	149	11 Sep	131
20 Mar	141	18 Sep	138
27 Mar	148	25 Sep	135
3 Apr	146	2 Oct	146
10 Apr	143	9 Oct	132
17 Apr	149	16 Oct	125
24 Apr	140	23 Oct	132
		30 Oct	138
1 May	129	6 Nov	133
8 May	140	13 Nov	136
15 May	145	20 Nov	126
22 May	148		
29 May	149		
5 Jun	144		
12 Jun	135		
19 Jun	113		
26 Jun	140		

Sources: See next page

Sources: The weekly series is found in 'Weekly Index of Total Munitions Production' (30 November 1942), and in subsequent issues of the *Weekly Progress Report*, including the Supplement to *WPR* no. 50 (also entitled 'Weekly Index of Total Munitions Production'), (13 April 1943), up to *WPR* no. 84 (10 December 1943) when the demise of the weekly index was announced.

Appendix B. *Munitions output of the UK: The monthly Robinson index, 1942-5*Table B-1. *The Robinson index, 1942-5 (monthly and quarterly series)*

	Weekly index, average ^a	Monthly index: ^b	
		Series A	Series B
1942:			
Jan			
Feb			
Mar			
<i>1st qtr</i>	100.0	100.0	100.0
Apr			
May			
Jun	123.0		
<i>2nd qtr</i>			
Jul	116.5		
Aug	115.0		
Sep	129.5	131.2	
<i>3rd qtr</i>	120.3		
Oct	135.2	135.2	
Nov	125.8	c. 130	
Dec	127.0	127	
<i>4th qtr</i>	129.3	130.7	
1943:			
Jan	130.8	131	
Feb	144.8	145	
Mar	146.0	146	
<i>1st qtr</i>	140.5	140.7	
Apr	144.5	146 ^c	
May	142.2	151.1	
Jun	133.0		
<i>2nd qtr</i>	139.9		

(continued)

Table B-1 (continued). *The Robinson index, 1942-5 (monthly and quarterly series)*

	Weekly index, average	Monthly index:	
		Series A	Series B
1943 (continued):			
Jul	132.0		
Aug	118.3		
Sep	137.0		
<i>3rd qtr</i>	<i>129.1</i>		
Oct	134.6	c. 150	
Nov	131.7 ^e	151.0	
Dec		142.1	
<i>4th qtr</i>		<i>147.7</i>	
1944:			
Jan		152.2	150
Feb		155.1	
Mar		165.5	161.2
<i>1st qtr</i>		<i>157.6</i>	
Apr		151.9	149.3
May		156.3	
Jun		153.6	147.0
<i>2nd qtr</i>		<i>153.9</i>	
Jul		138.9	133.0
Aug			133.7
Sep			140.7
<i>3rd qtr</i>			<i>135.8</i>
Oct			142.4
Nov			138.3
Dec			115.8
<i>4th qtr</i>			<i>132.2</i>

(continued)

Table B-1 (continued). *The Robinson index, 1942-5 (monthly and quarterly series)*

	Weekly index, average	Monthly index:	
		Series A	Series B
1945:			
Jan			108.7
Feb			127.9
Mar			126.6
<i>1st qtr</i>			121.0
Apr			105.4
May			95.4
Jun			95.8
<i>2nd qtr</i>			98.8

Notes and sources:

- a The monthly and quarterly averages of the weekly index are calculated from Appendix A.
- 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 by me.
- c First three weeks only.

Appendix C. *Quarterly munitions production for the three supply departments, 1938-45*

Table C-1. *Measures of output for the Ministry of Supply, Ministry of Aircraft Production and Admiralty (1938-45, quarterly series)*

Year/Qtr	Min. of Supply index of total completed warlike stores (Sept.-Dec. 1939 = 100) ^a	Total structure weight of completed aircraft: ^b		Total displacement of completed warships, thou tons ^c
		Crude, mn lbs	Adjusted for man-hours, index (Jan. 1942 = 1,000)	
1938 1st		1.77	71	4.2
2nd		1.90	73	9.7
3rd		2.47	96	40.9
4th		3.68	138	33.9
1939 1st		6.13	232	21.6
2nd		6.93	266	17.6
3rd		7.50	288	29.3
4th	100 ^d	8.33	314	25.7
1940 1st		8.86	335	14.6
2nd		15.67	589	64.8
3rd	238.3	18.23	682	68.8
4th	242.0	16.07	602	114.9
1941 1st	271.0	18.70	694	107.5
2nd	307.3	20.90	774	101.2
3rd	353.7	23.51	865	74.8
4th	421.3	24.14	880	153.7
1942 1st	609.0	27.51	1001	68.0
2nd	714.0	32.41	1165	158.5
3rd	735.7	35.46	1241	137.2
4th	797.1	38.00	1328	117.7
1943 1st	798.7	42.64	1473	119.4
2nd	763.7	46.61	1591	153.6
3rd	687.0	46.11	1585	152.9
4th	704.3	49.89	1698	183.4

(continued)

Table C-1 (continued). *Measures of munitions output for the Ministry of Supply, Ministry of Aircraft Production and Admiralty (1938-45, quarterly series)*

Year/Qtr	Min. of Supply index of total completed warlike stores (Sept.-Dec. 1939 = 100) ^a	Total structure weight of completed aircraft: ^b		Total displacement of completed warships, thou tons ^c
		Crude, mn lbs	Adjusted for man-hours, index (Jan. 1942 = 1,000)	
1944 1st	703.0	56.47	1919	167.0
2nd	653.3	55.31	1885	174.6
3rd	584.0	50.40	1718	116.1
4th	600.7	46.34	1573	125.7
1945 1st		42.87	1466	102.6
2nd		31.95	1092	125.3
3rd		19.80		84.9

Notes and sources:

- a Calculated from monthly series in Postan, *British war production*, 174, 354.
- b See the *Statistical digest*, 153-4 for crude structure weight (quarterly series) and adjusted structure weight (monthly series, from which the quarterly entries above have been calculated).
- c Calculated by summing across thirteen warship classes listed in *Statistical digest*, 133-4.
- d September to December, inclusive.

Appendix D. *Estimates of quarterly employment on Admiralty orders, 1941-5*

The change in employment on Admiralty orders played an important role in the Robinson index. This is because, in the absence of a satisfactory measure of production of completed warships, Robinson used lagged employment on Admiralty contracts as a proxy measure of output.

Continuous, revised Ministry of Labour quarterly figures for employment in munitions production under each of the three supply departments for December 1940-June 1945 were published in 1957. But these differed very significantly from the estimates current in war time. I needed to establish the employment estimates actually available to Robinson and his staff 'on a Saturday morning in wartime', in order to be sure that I knew how the Robinson index was compiled.

The employment data available at the time were not very satisfactory. Employment on Admiralty contracts was evidently not to hand for the period before December 1941. This was only one and a half months before the midpoint of Robinson's base period, three months short of the four and a half month lag specified by Robinson for use of employment as a proxy for warship completion. A weekly series of 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 December 1941, and from August 1942 attempts were made to estimate employment in the intervening months. These are available from the monthly *Surveys*. However, the monthly estimates frequently turned out to understate the apparently rapid underlying change in munitions employment when the results of quarterly censuses became available. This gives rise to another problem: there were no continuous series for the whole war period but rather several discontinuous, overlapping series reflecting succeeding revisions.

In fact, Robinson's staff had four distinct and overlapping primary series to draw on in order to derive a continuous series for wartime employment in the munitions industries. In Table D-1, these series are labelled by the letters 'A' through 'D'. They are best described as follows:

Series A This ran from 31 December 1941 to 30 June 1942, recording an increase in total employment on munitions orders from 2.987 millions to 3.346 millions.

Series B At the end of June 1942 there was a minor revision; total estimated employment remained unchanged, but a few employees of the Royal Ordnance Factories were

transferred to reported employment under the Ministry of Supply from the other two departments. Series B now ran from 30 June 1942 to 5 December 1942. By this stage, there were attempts to estimate employment between censuses, although not at regular intervals.

Series C At the end of December 1942 there was a major revision of estimated growth in employment. It was now reckoned that total June 1942 employment had been 3.984 millions, not the 3.346 millions previously recorded. The increase was shared between the three supply departments. Series C ran from December 1942 (with revisions going back to 30 June 1942) until 31 December 1943, when reported total employment stood at 4.189 millions (this was slightly below the wartime peak of 4.217 millions estimated on 31 August 1943). Monthly estimates were also supplied from 30 June 1943.

Series D In early 1944 a minor revision raised estimated total employment on 31 December 1943 from 4.189 millions to 4.203 millions (in *Survey* no. 23), but the new series was overtaken at the end of 1944 by a further revision which put estimated December 1943 employment still higher at 4.209 millions (in *Survey* no. 31). This was Series D, and it ran now until 31 March 1945.

These series are combined in the table in order to yield a continuous run of data from 31 December 1941 to 31 March 1945. The result is not a new, reliable measure of wartime employment on Admiralty orders since it is clearly at variance with the postwar revised estimates published by Inman. It is a measure of employment *which might reasonably, if wrongly, have been regarded as reliable at the time.*

First, Series A is chained onto Series B in the conventional way. The new series (say, Series B-1) now runs back to 31 December 1941.

Second, Series B-1 must be revised in the light of Series C. I make the assumption that the new figure for 31 December 1941 (Series B-1) was regarded as reliable, but that Series B-1 was seen to have understated the subsequent growth of munitions employment. I take to have been firm the Series C figure for 30 June 1942. One option would be a simple linear interpolation between December 1941 (Series B-1) and June 1942 (Series C), but I reject this on the grounds that none of the series available show any sign of linearity. Instead, I take the figure for March 1942 (Series B-1) and calculate an adjustment factor based on the proportion of the total change in employment between December 1941 and June 1942 achieved by March within Series B-1. I then apply this adjustment factor to the total change in employment between December 1941 (Series B-1) and June 1942 (Series C).

Series C also lacks an entry for 30 September 1942. This is obtained from Series B, multiplied by the proportion of Series C to Series B for 30 June 1942. This gives us a new series (say, C-1) which runs continuously from the end of 1941 to the end of 1943.

Third, Series C-1 must now be reconciled with Series D. I assume Series D to have been a firm estimate. However, I do not consider it safe to assume that Series C-1 should be chained on in the conventional way, which would mean a small deflation of every entry for the preceding two years. Instead, I graft it onto Series D in the same way that Series B-1 was grafted onto Series C. I continue to assume that the existing figure for 30 June 1942 (Series C) is firm, and I adjust intervening entries up to the end of 1943 by a similar adjustment factor.

The outcome is the series called 'adjusted' in the table. Let me repeat that 'adjusted' does not mean 'correct'. The 'adjusted' series may, however, reasonably have been regarded as correct at the time, in light of the information then available.

The last point to be explained is that, in order to find out how the original Robinson index worked, we need a figure for employment on Admiralty orders as of 30 September 1941 - before the initiation of Series A. This is in order to apply the necessary lag to employment as an indicator of output. Here there is no alternative to backward linear extrapolation. I take the change in employment on Admiralty orders during 1941 (4th quarter) to be an average of the change in the following four quarters, and establish a September 1941 figure on this basis.

Table D-1. *Estimates of quarterly employment on Admiralty orders, 1941-5 (thousands)*

Year/Qtr	End of quarter employment:					
	Series A	Series B	Series C	Series D	Adjusted	Inman (1957)
1940 4th						619.7
1941 1st						619.9
2nd						642.4
3rd					627.5 ^a	656.8
4th	678				673.3	676.4
1942 1st	695				727.7	685.8
2nd	722	717	814		814.0	704.7
3rd		737			836.7	728.9
4th			854		856.7	741.9
1943 1st			875		879.1	766.0
2nd			895		900.4	786.8
3rd			914		920.7	805.3
4th			911.5	918.0	918.0	806.5
1944 1st				908.9	908.9	806.1
2nd				896.5	896.5	793.2
3rd				878.0	878.0	780.3
4th				850.0	850.0	756.1
1945 1st				818.7	818.7	720.1
2nd						667.7

Sources:

Series A Survey no. 4 for July 1942.

Series B Surveys nos. 4-9 for July-December 1942.

Series C Survey no. 21 for December 1943.

Series D Surveys nos. 23, 25, 27, 31, 35, 37-8 for various months between February 1944 and May 1945.

Adjusted See text of Appendix.

Note:

^a Estimated by backward linear extrapolation from the average change in employment over 1942.

Footnote references

(A) Official papers

Papers of Sir Austin Robinson, Churchill Archives Centre, Churchill College, Cambridge:

- File 2/6/1 *Weekly Progress Reports of the Ministry of Production (Planning and Programmes Department, later Programmes Division), May 1942-December 1944. Including 'Weekly Index of Total Munitions Production' (30 November 1942) and Supplement to Weekly Progress Report no. 50, also entitled 'Weekly Index of Total Munitions Production', (13 April 1943)*
- File 2/6/2 *Weekly Progress Reports, 1945*
- File 2/6/3 *Surveys of United Kingdom Production of the Ministry of Production (Planning and Programmes Department, later Programmes Division), April-December 1942*
- File 2/6/4 *Surveys, 1943*
- File 2/6/5 *Surveys, 1944-5*

(B) Publications

- Die deutsche Industrie im Kriege 1939-1945* (Berlin, 1954)
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- Ralph E. Smith, *The Army and economic mobilization* (Washington, D.C., 1959)
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(C) Unpublished papers

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